

Climatic Implications for Restoration of Ecosystems on the Colorado Plateau Under a Changing Climate

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Oregon Convention Center, Portland, OR*



“All is flux, nothing is stationary; Nothing endures but change”

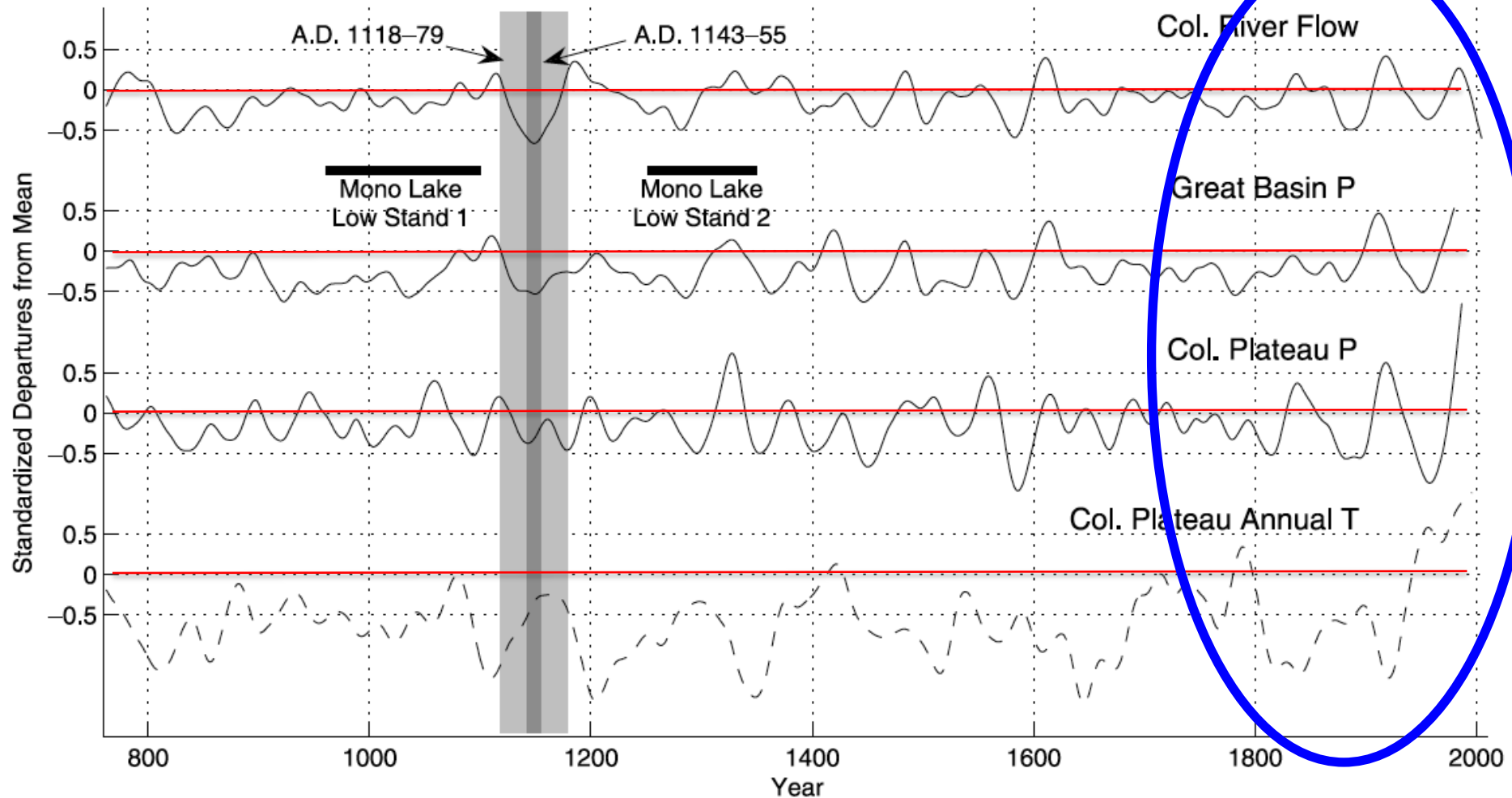
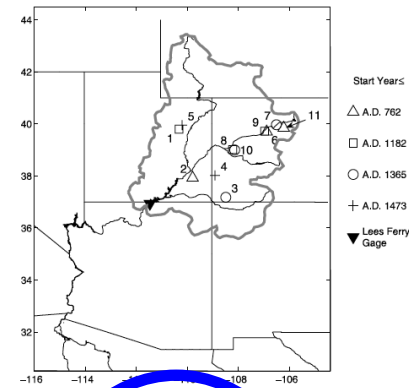
....Heraclitus (540 – 475 BC)

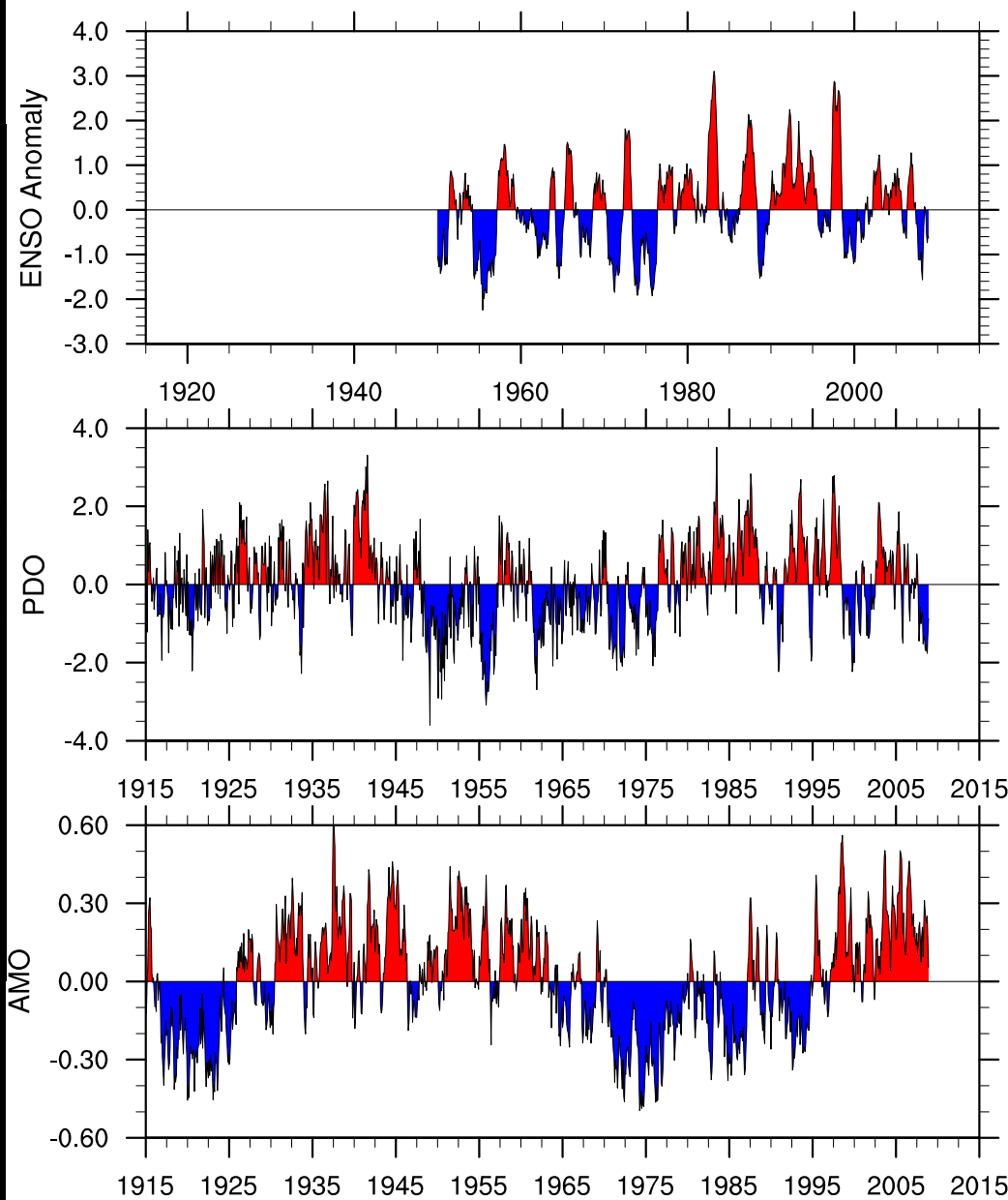
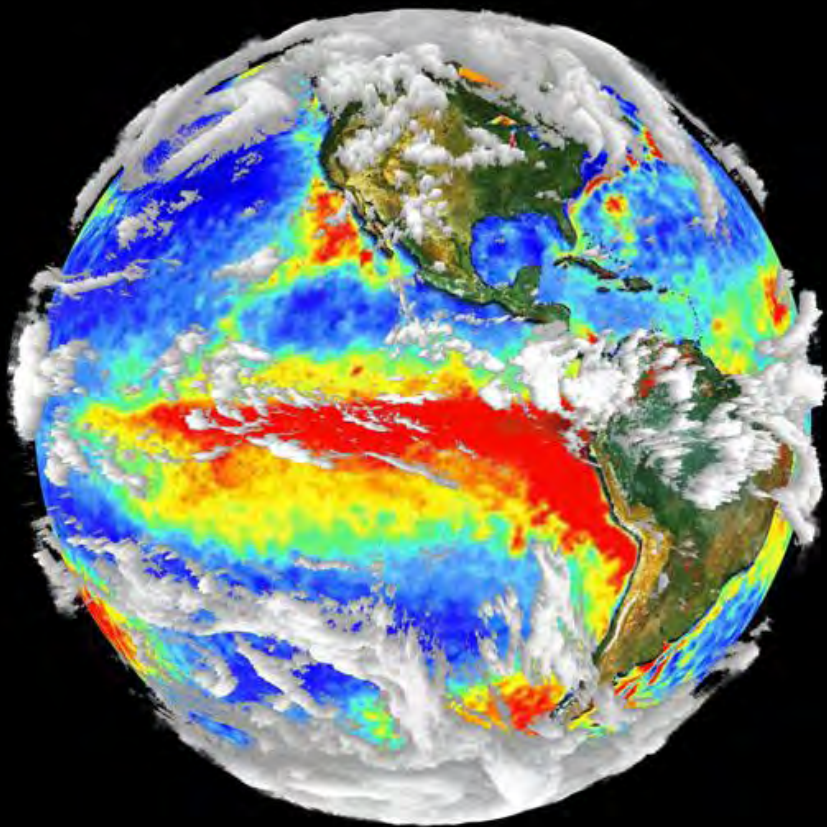


Medieval Drought on the Colorado River

(From tree-ring reconstructions)

Meko et al. 2007





Data Source:

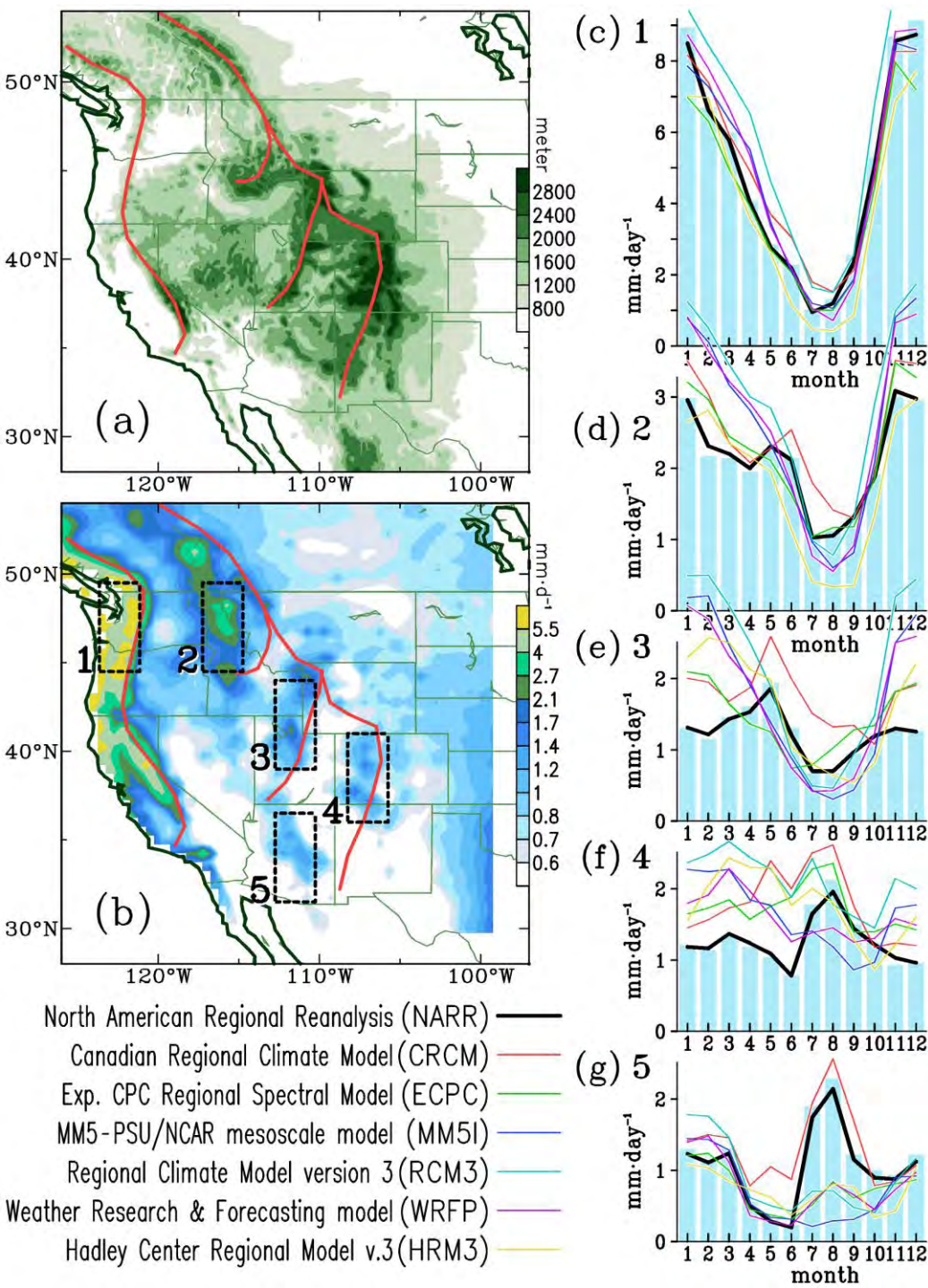
AMO: NOAA <http://www.cdc.noaa.gov/data/timeseries/AMO/>

PDO: ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/PDO.latest

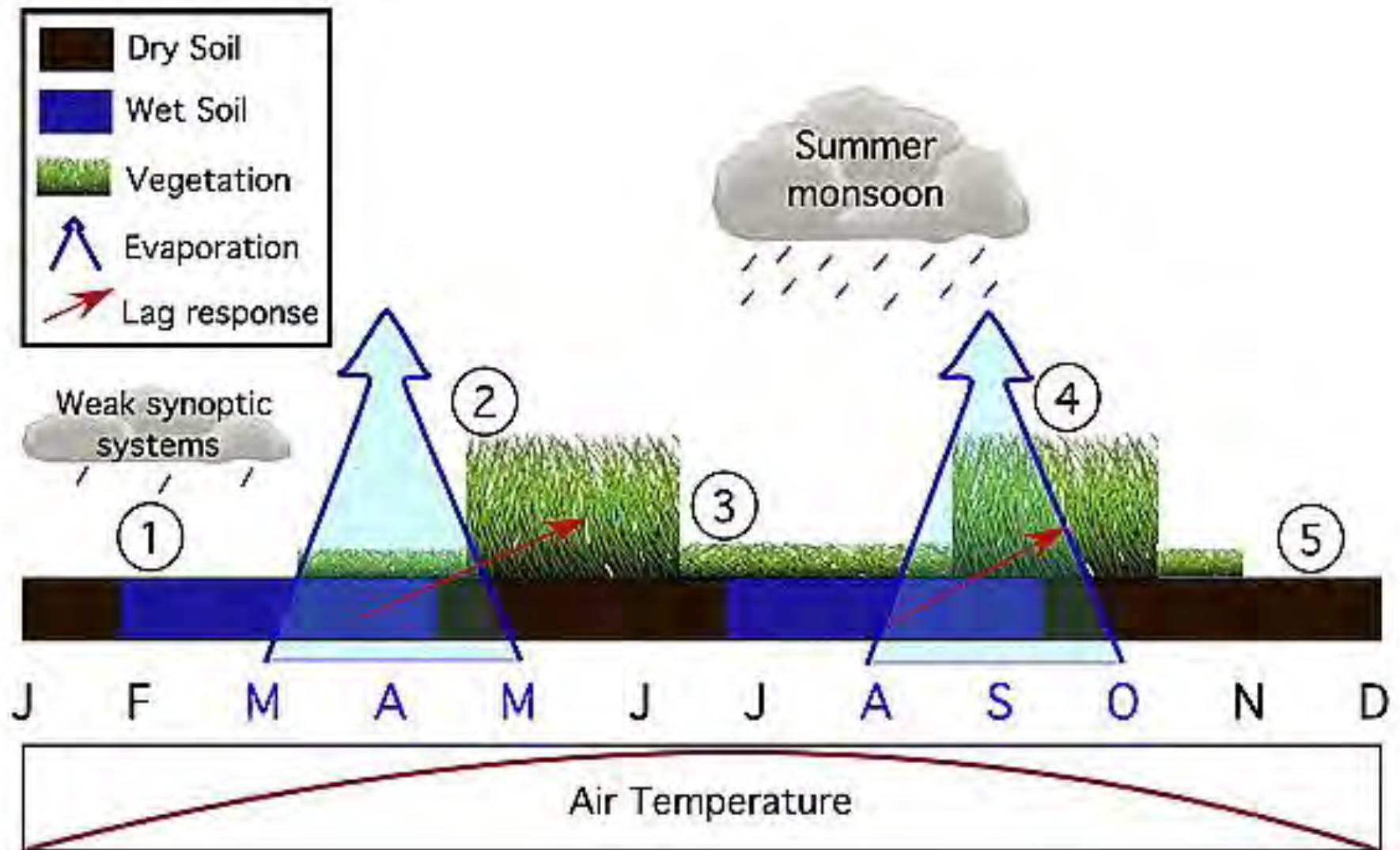
ENSO: NOAA <http://www.cdc.noaa.gov/people/klaus.wolter/MEI/mei.html>

Precipitation Patterns Across the Intermountain West

Wang et al., 2009

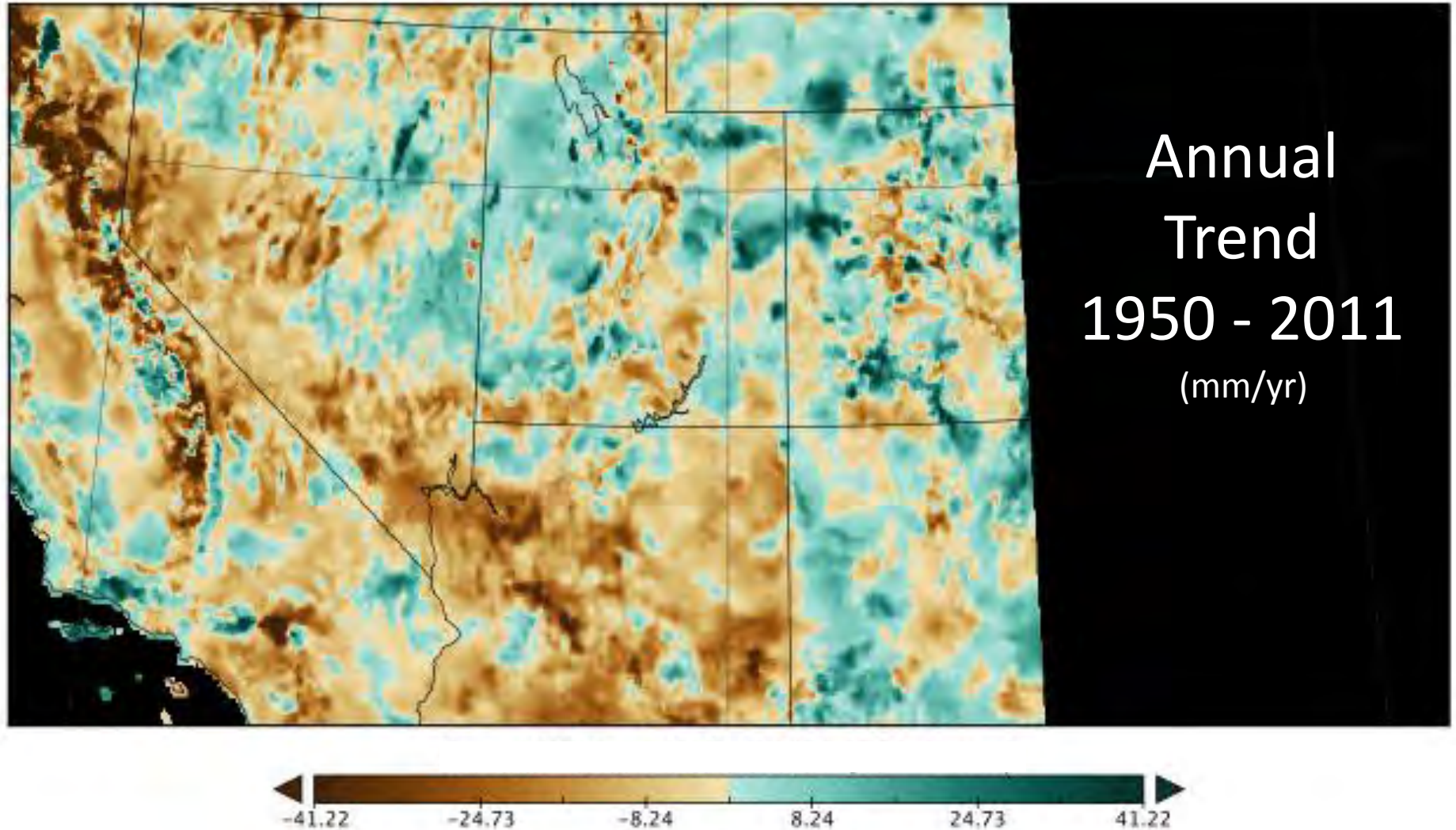


Wang, S.-Y., R. R. Gillies, E. S. Takle, and W. J. Gutowski Jr. (2009), Evaluation of precipitation in the Intermountain Region as simulated by the NARCCAP regional climate models, *Geophys. Res. Lett.*, 36, L11704, doi:10.1029/2009GL037930.

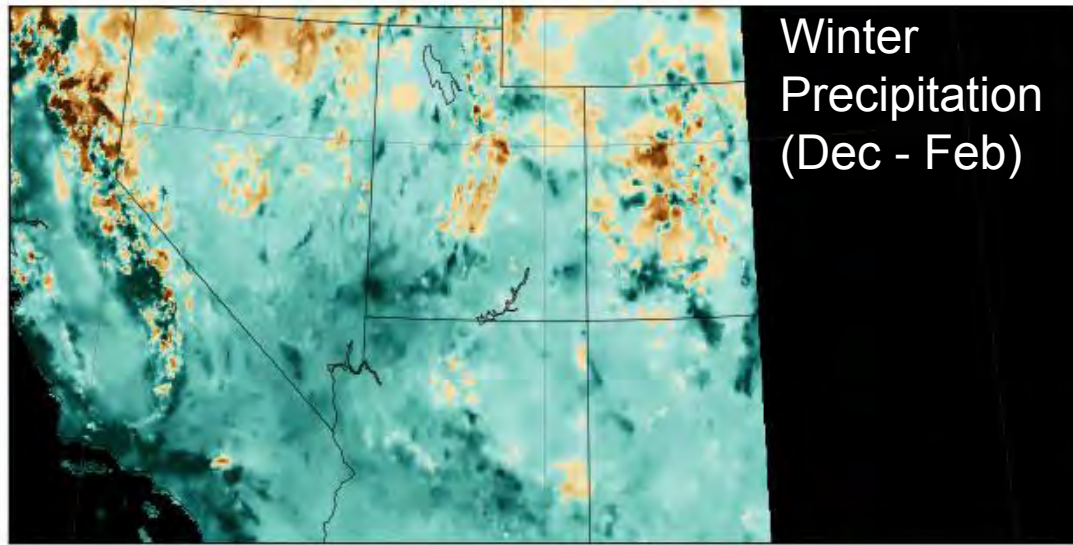


Notaro, M., Z. Liu, R. G. Gallimore, J. W. Williams, D. S. Gutzler, and S. Collins (2010), Complex seasonal cycle of ecohydrology in the Southwest United States, J. Geophys. Res., 115, G04034, doi:10.1029/2010JG001382.

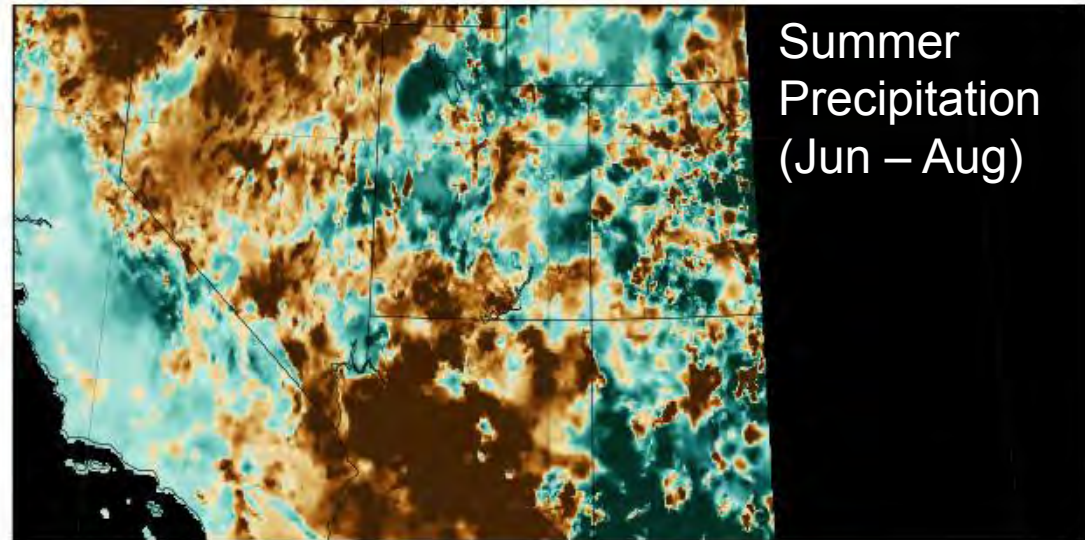
Trend in Annual Moisture Availability (PPT minus PET)

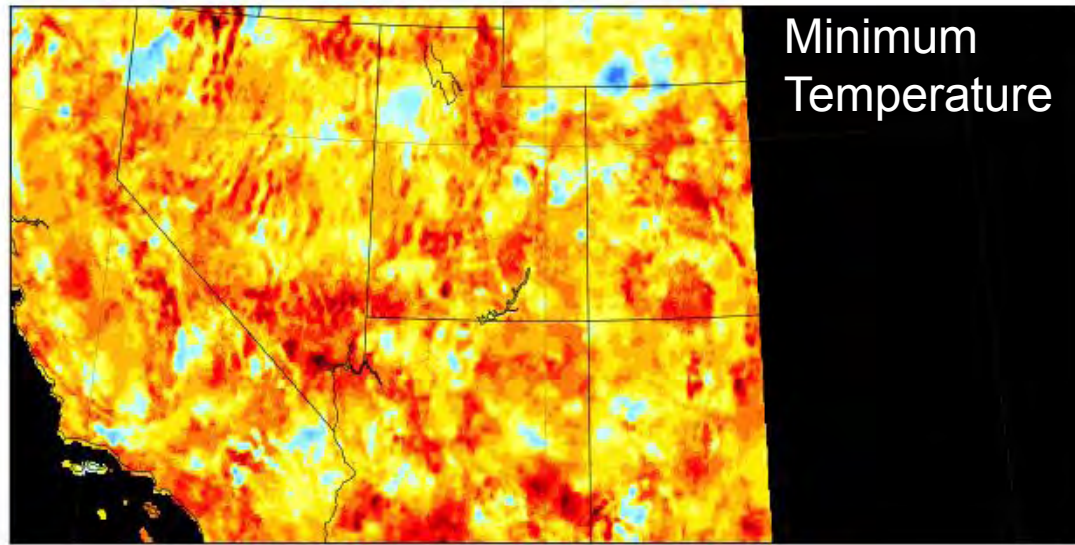


Data source: Daly et al 2007. 103-Year High-Resolution Temp
the Conterminous United States. Online [URL:ftp://ftp.ncdc.noaa.gov/pub/data/prism100](ftp://ftp.ncdc.noaa.gov/pub/data/prism100)

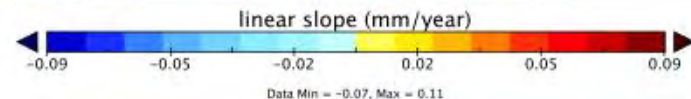
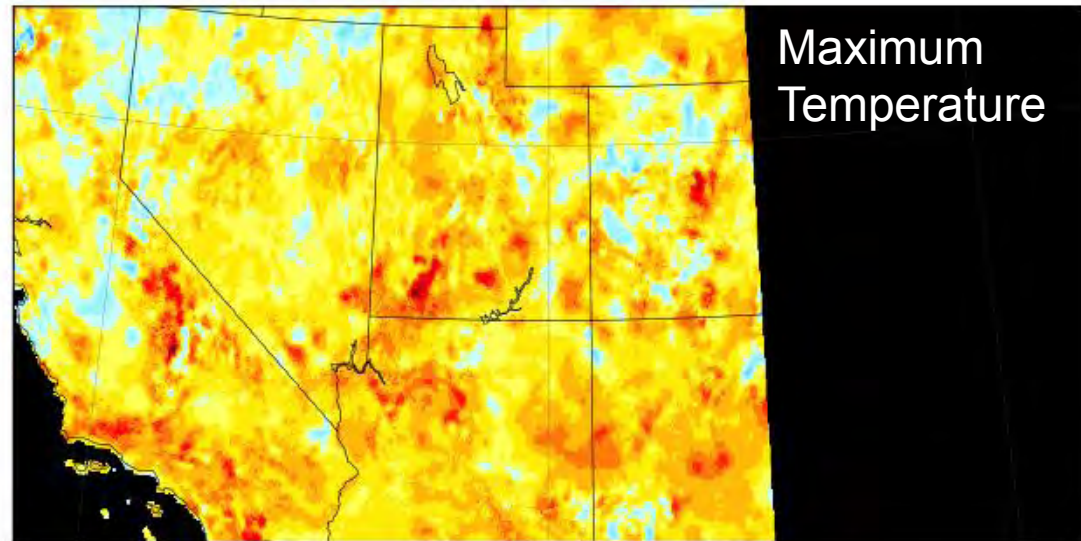
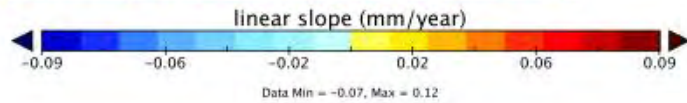


Trends in Winter and Summer Precipitation 1950 - 2011

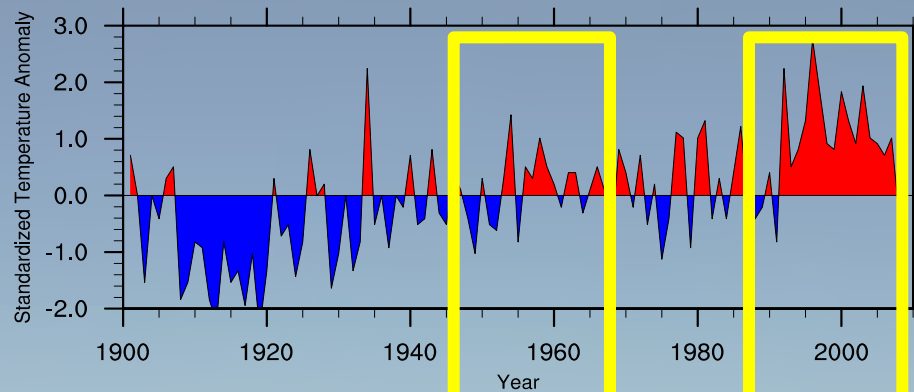




Trends in Spring Temperature 1950 - 2011



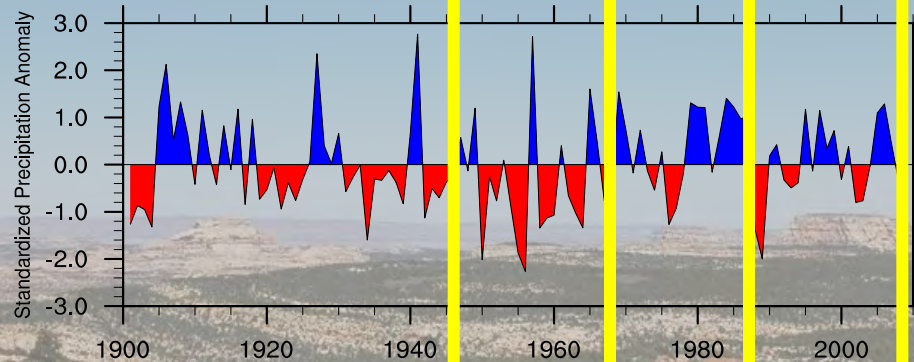
Annual
Temperature



Extremely Warm

Extremely Cool

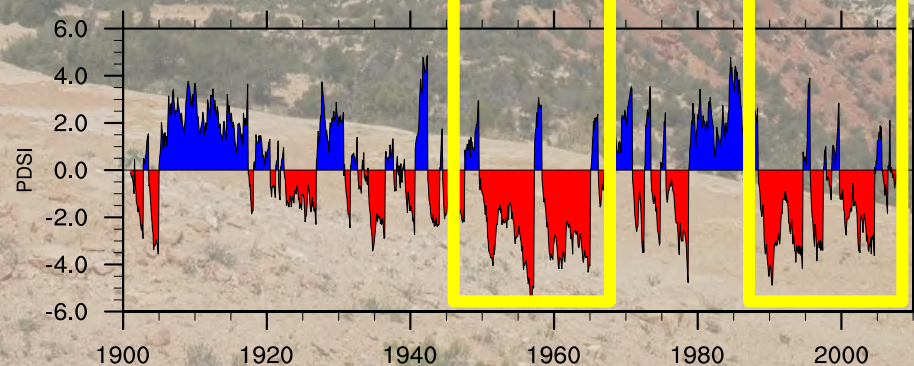
Annual
Precipitation



Extremely Rainy

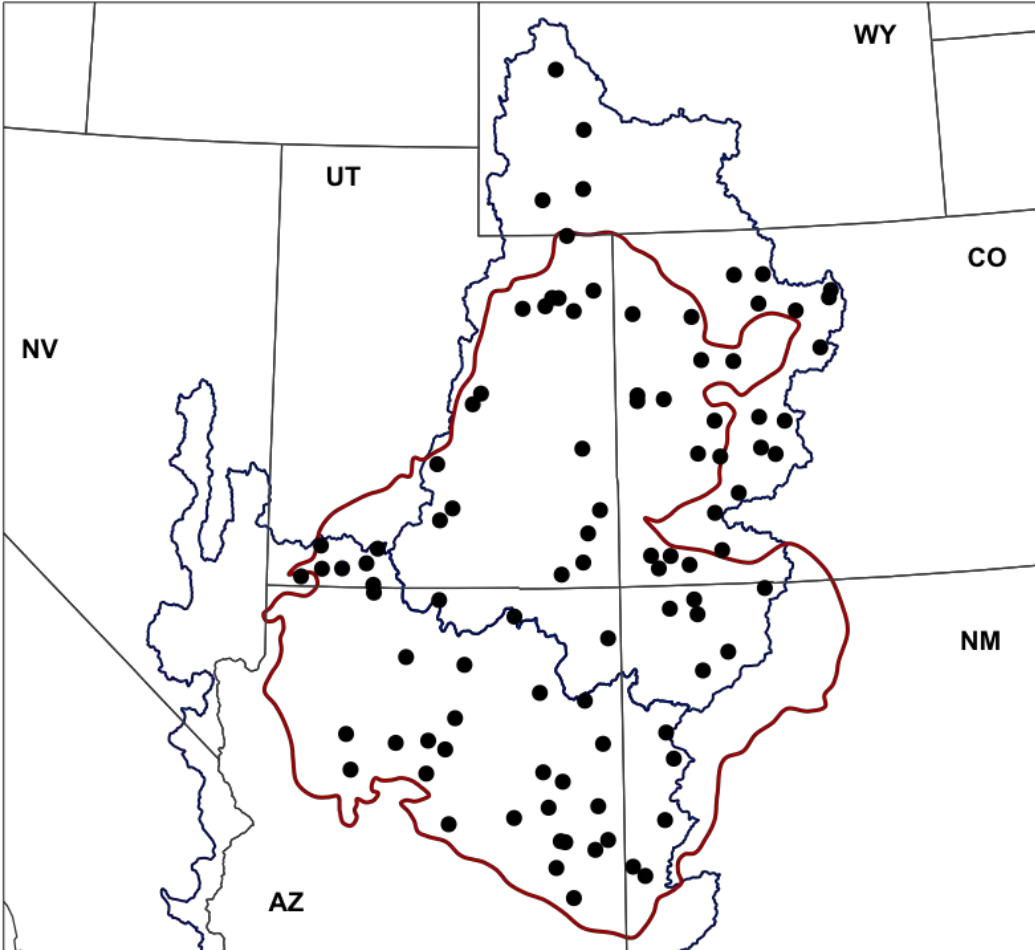
Extremely Dry

Drought
Index



Extremely Wet

Extremely Dry



National Climate Data Center Climate Division Stations (Data Adjusted for Inhomogeneities)

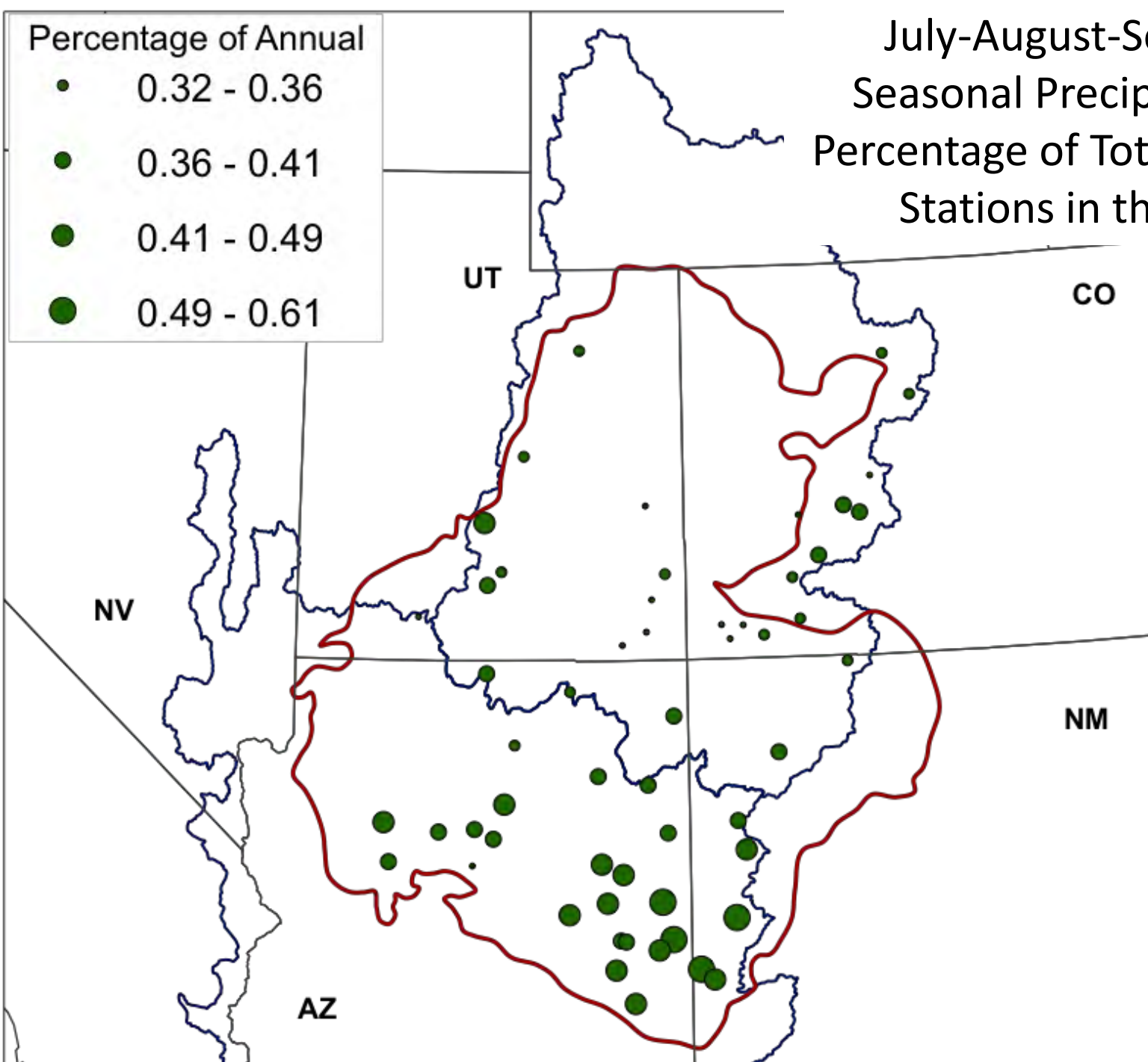
96 Stations with complete
monthly records for the
years 1950 – 2011

Elevational Range: 844 – 2814 m
Latitudinal Range: 33.47° – 42.88° N

Percentage of Annual

- 0.32 - 0.36
- 0.36 - 0.41
- 0.41 - 0.49
- 0.49 - 0.61

July-August-September
Seasonal Precipitation as a
Percentage of Total Annual for
Stations in the Region



Percentage of Annual

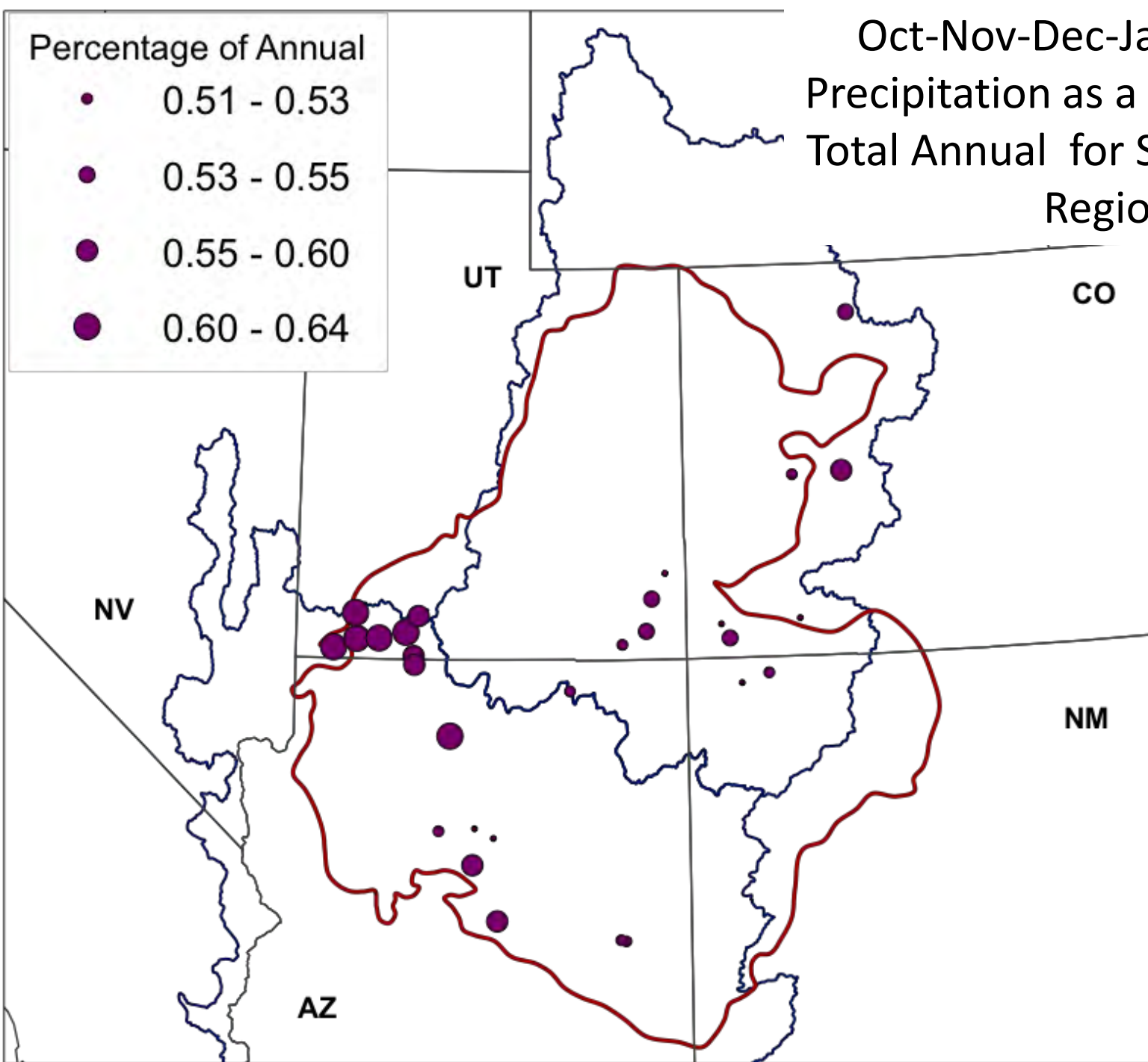
• 0.51 - 0.53

• 0.53 - 0.55

• 0.55 - 0.60

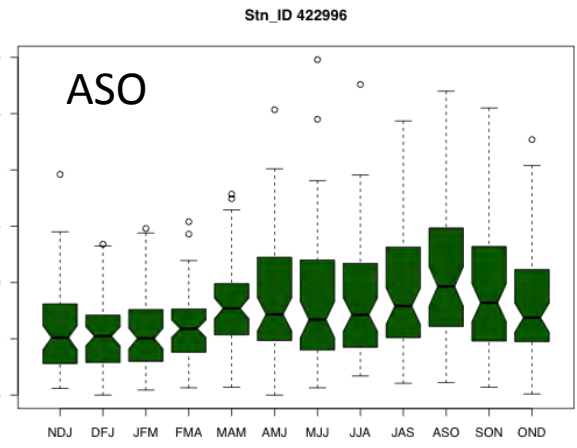
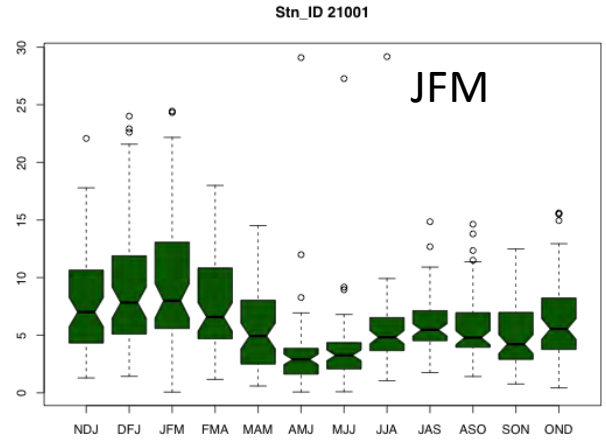
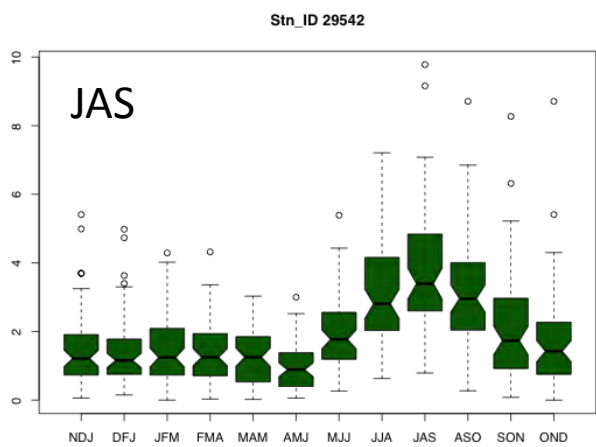
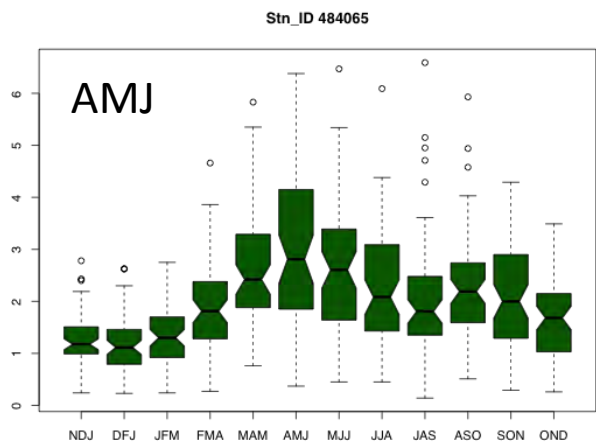
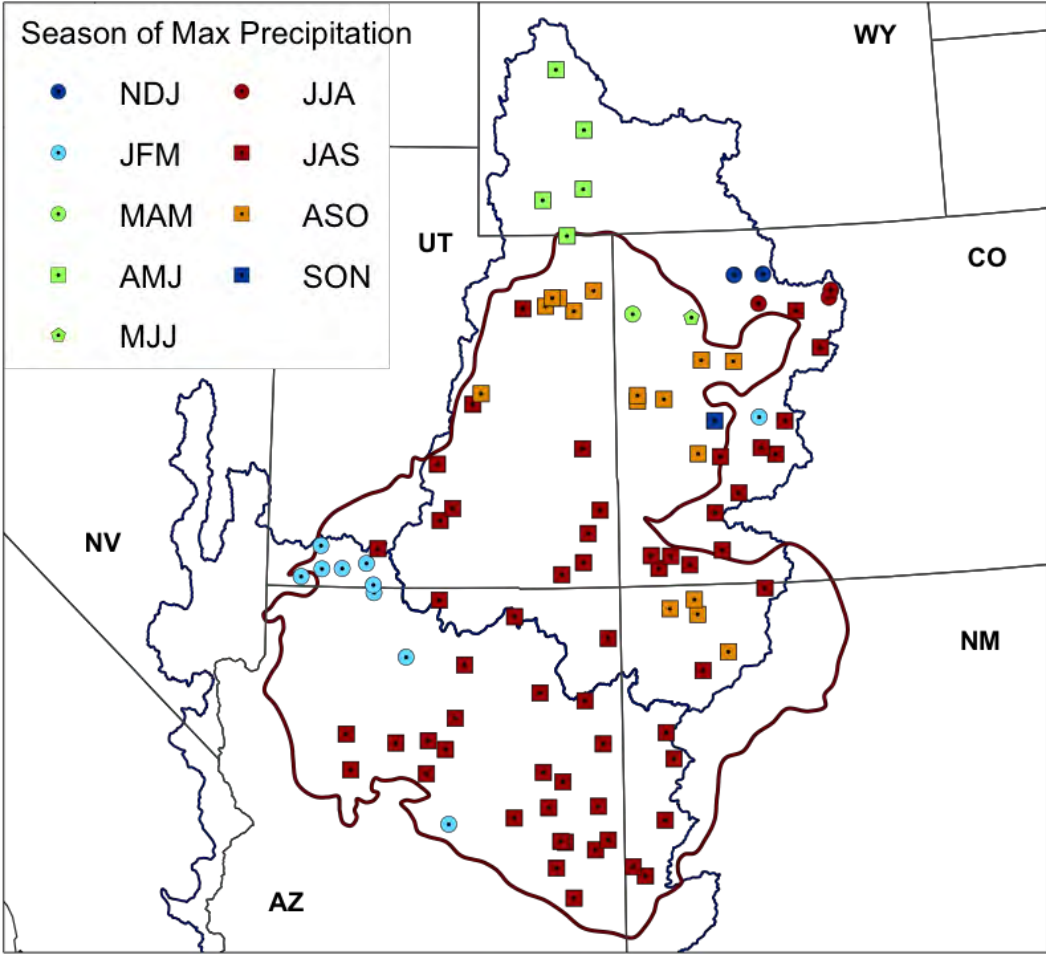
• 0.60 - 0.64

Oct-Nov-Dec-Jan-Feb-Mar
Precipitation as a Percentage of
Total Annual for Stations in the
Region

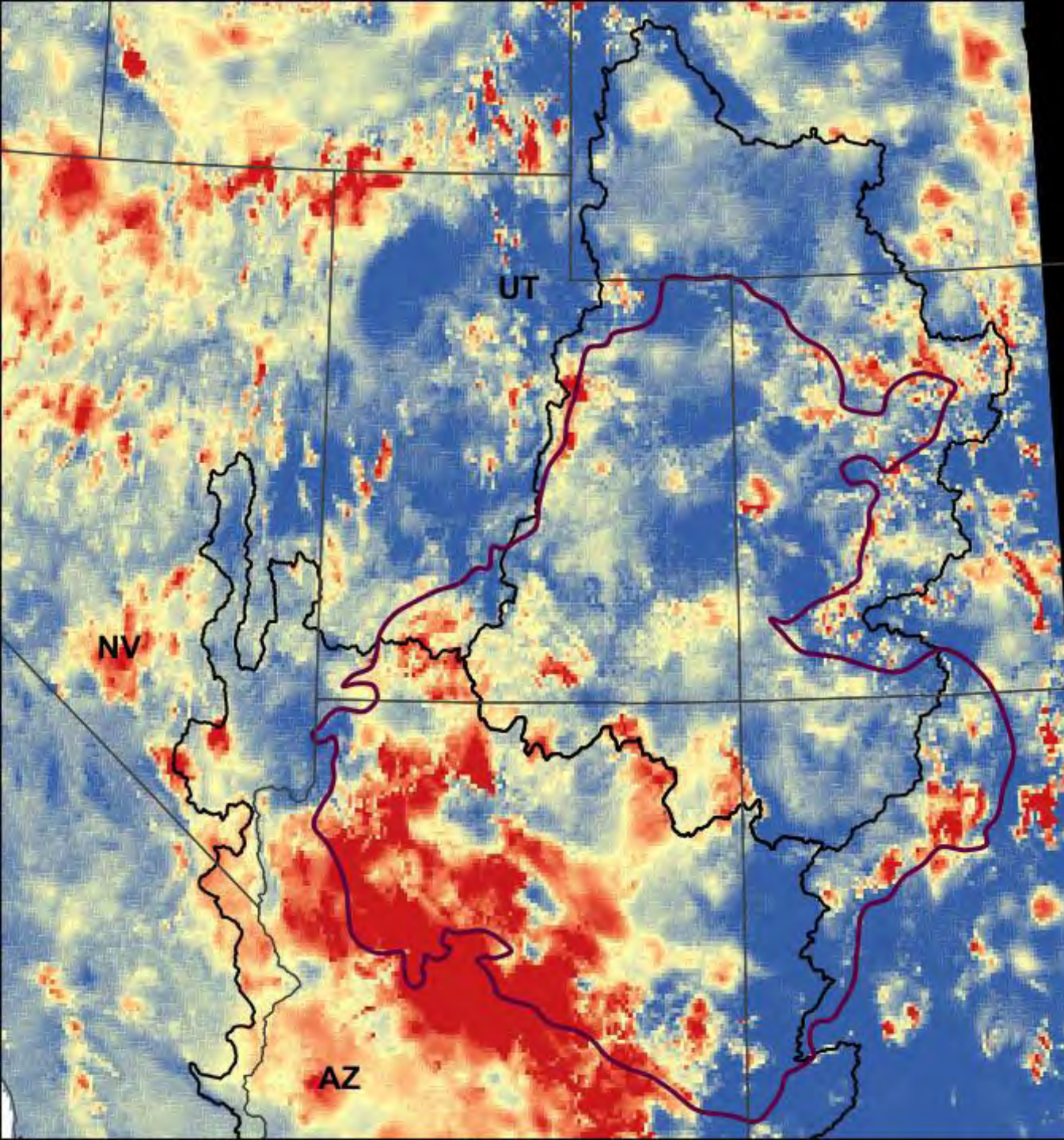


Season of Max Precipitation

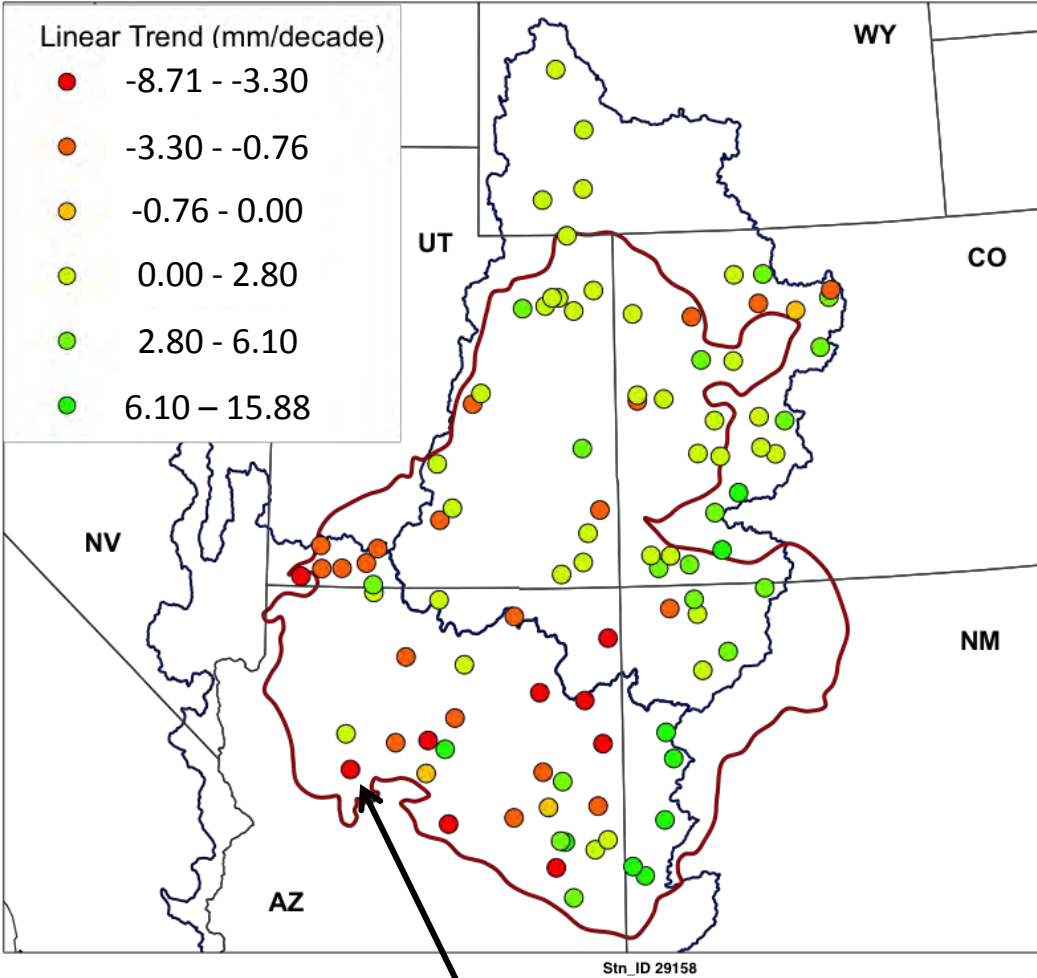
- NDJ
- JFM
- MAM
- AMJ
- MJJ
- JJA
- JAS
- ASO
- SON



Annual Trend (1950-2011) for Jul-Aug-Sept Precipitation



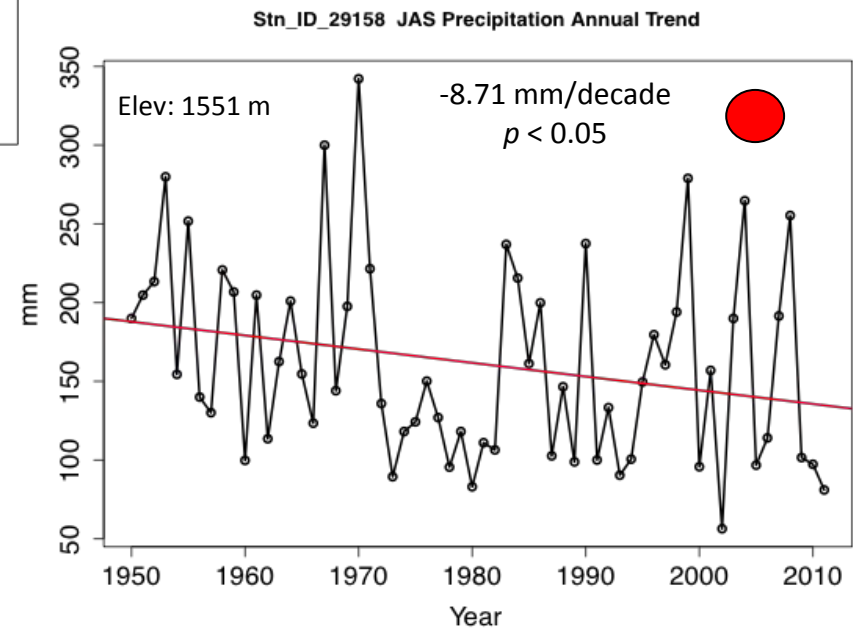
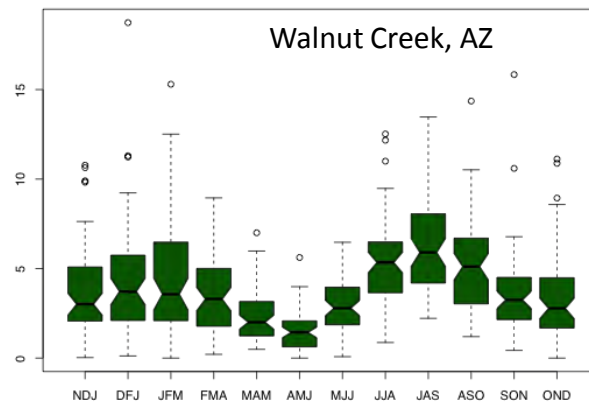
Data source: Daly et al 2007. 103-Year High-Resolution Temperature Climate Data Set for the Conterminous United States. Online
[URL:ftp://ftp.ncdc.noaa.gov/pub/data/prism100](ftp://ftp.ncdc.noaa.gov/pub/data/prism100)

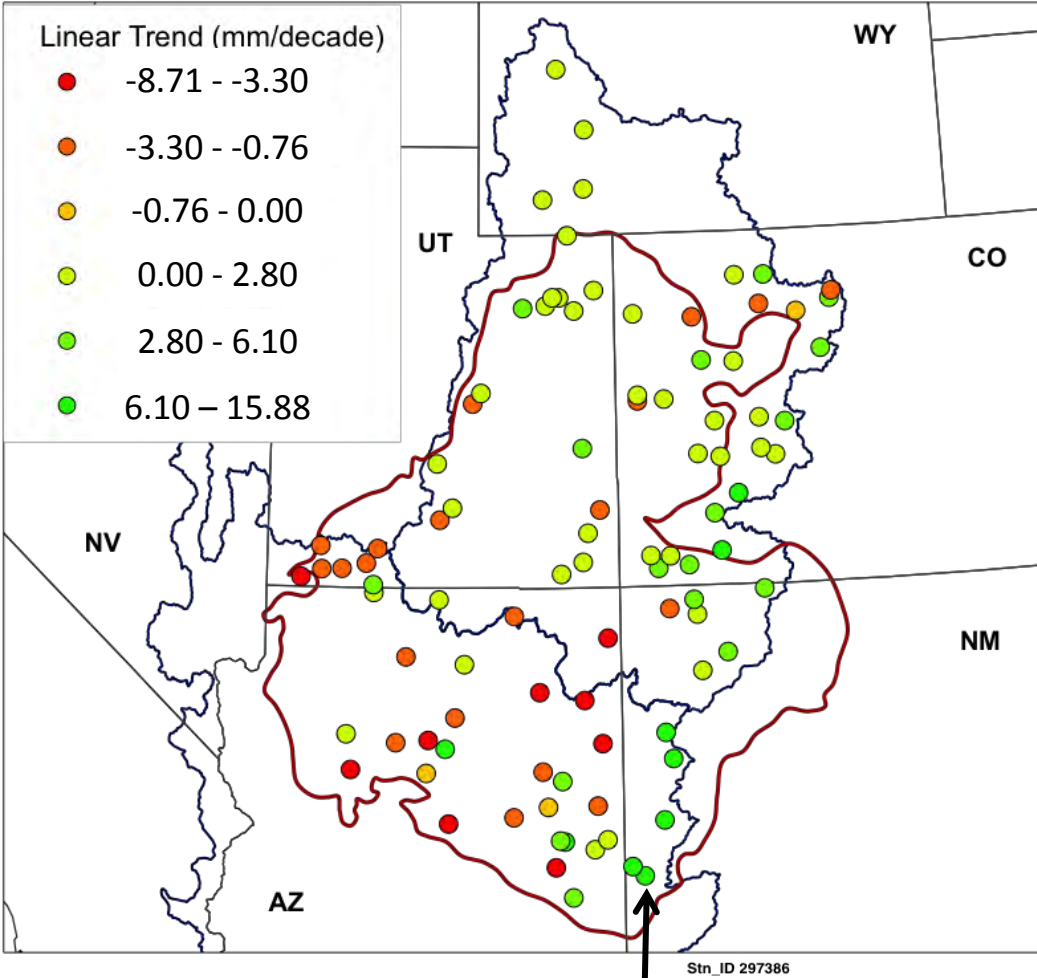


Annual Trend (1950-2011) in July-August-September Seasonal Precipitation for Stations in the Region

15 of the 96 station have significant trend $p < 0.1$

3 of the 15 stations ↓

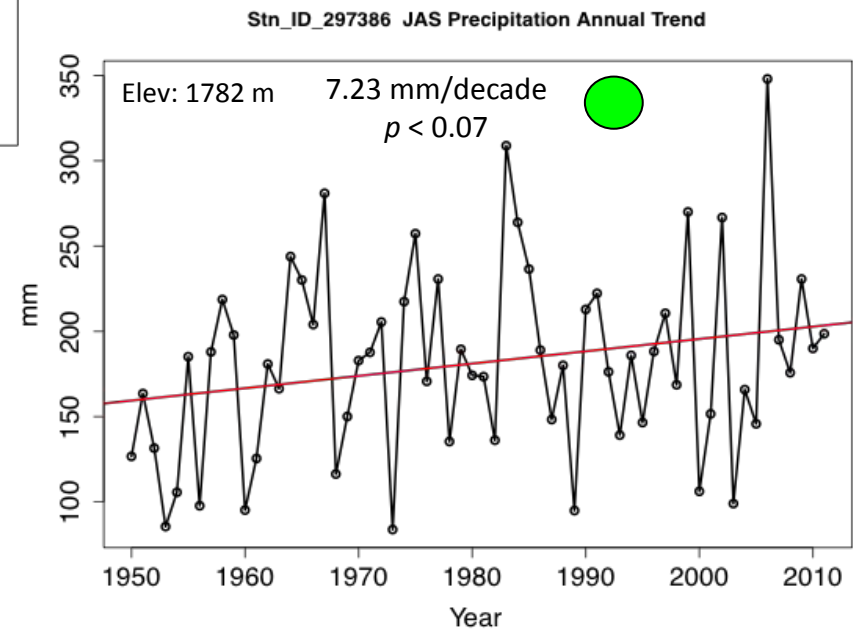
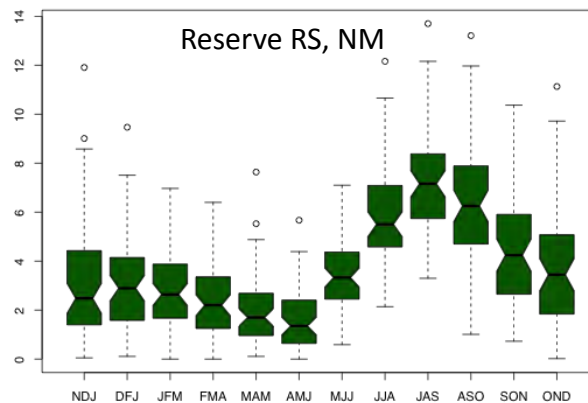




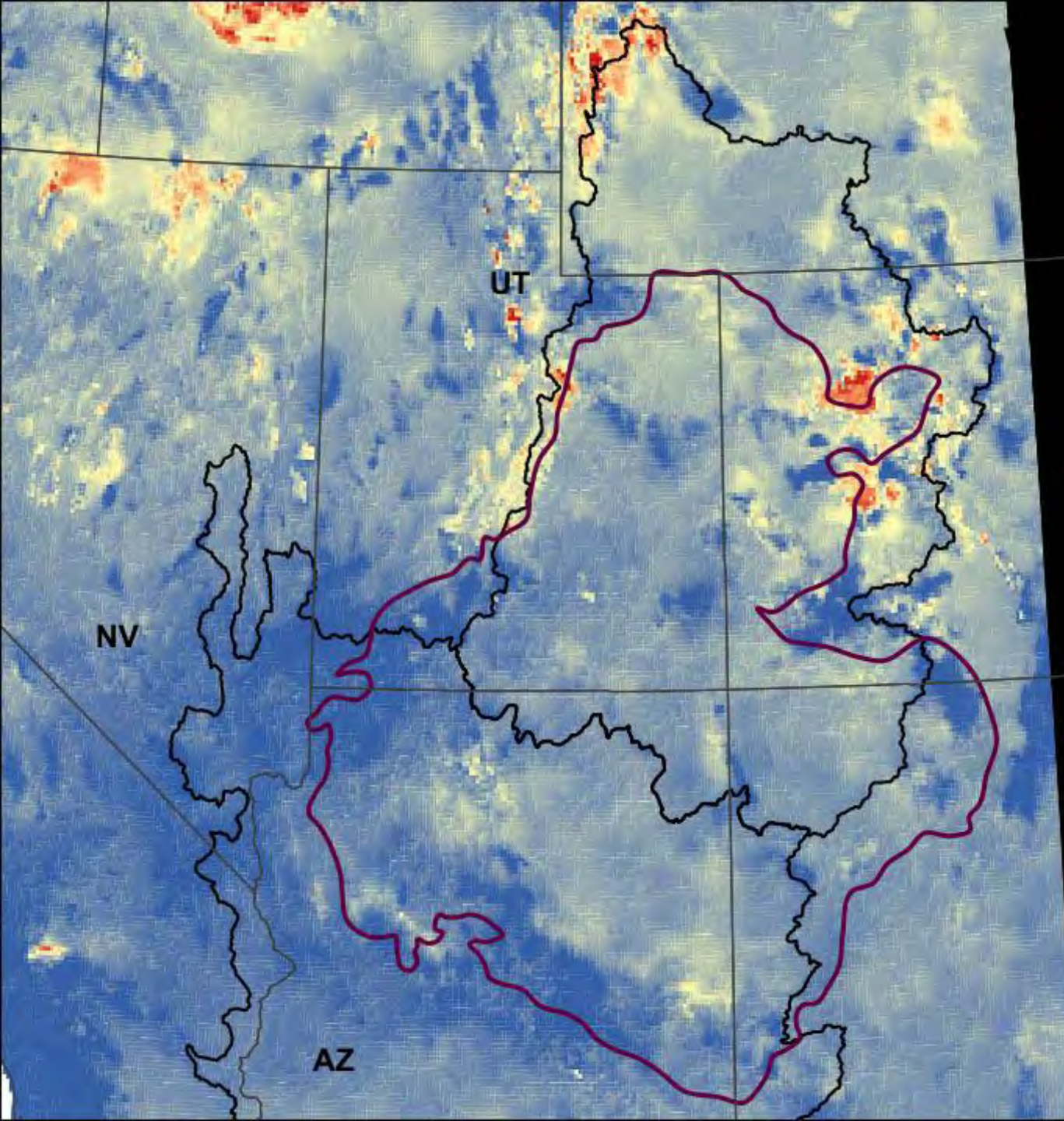
Annual Trend (1950-2011) in July-August-September Seasonal Precipitation for Stations in the Region

15 of the 96 station have significant trend $p < 0.1$

12 of the 15 stations ↑



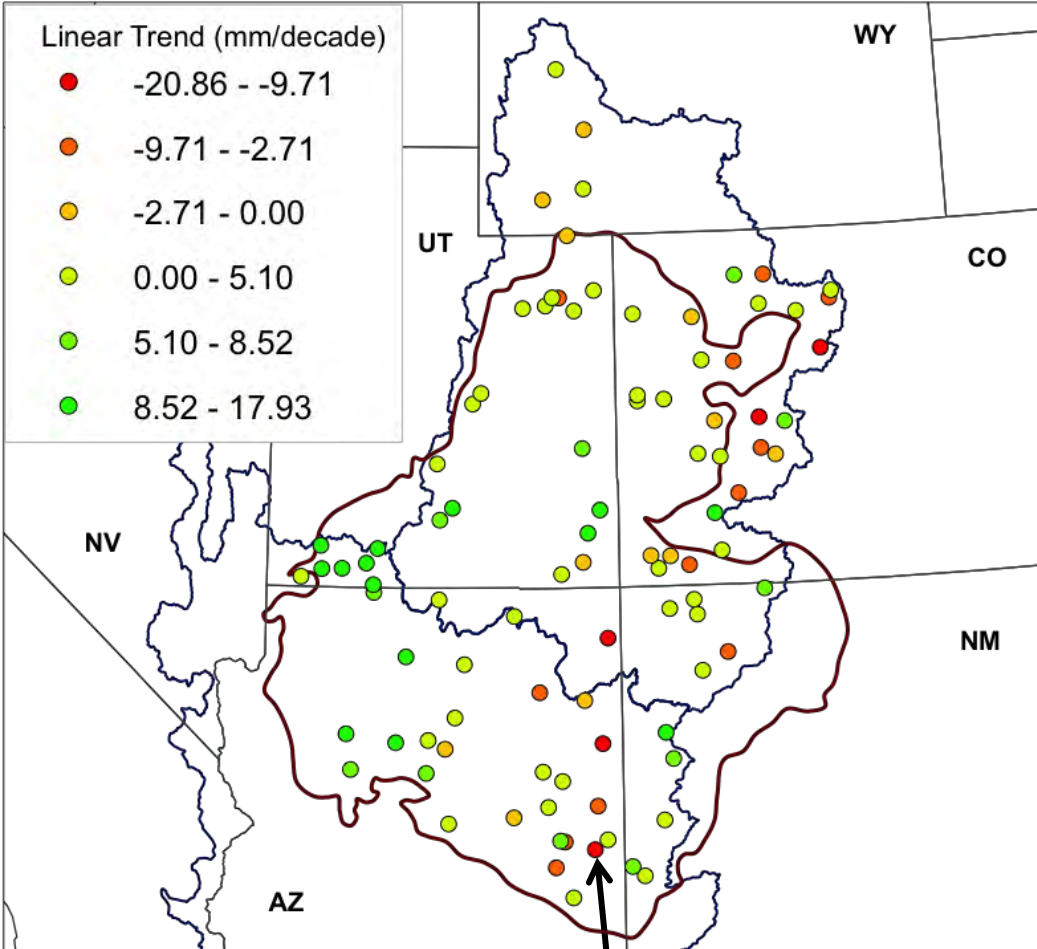
Annual Trend (1950-2011) for Winter Precipitation



Data source: Daly et al 2007. 103-Year High-Resolution Temperature Climate Data Set for the Conterminous United States. Online
[URL:ftp://ftp.ncdc.noaa.gov/pub/data/prism100](ftp://ftp.ncdc.noaa.gov/pub/data/prism100)

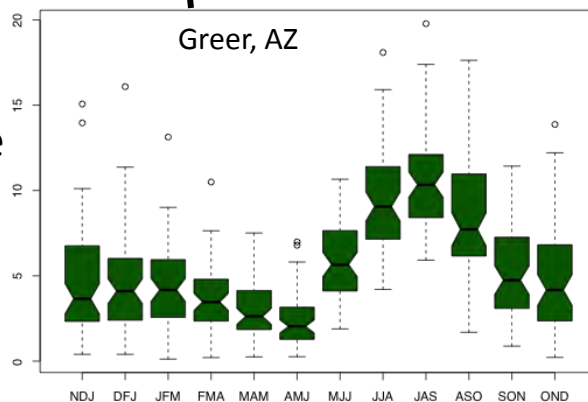
Linear Trend (mm/decade)

- -20.86 - -9.71
- -9.71 - -2.71
- -2.71 - 0.00
- 0.00 - 5.10
- 5.10 - 8.52
- 8.52 - 17.93



Stn_ID 23683

Greer, AZ

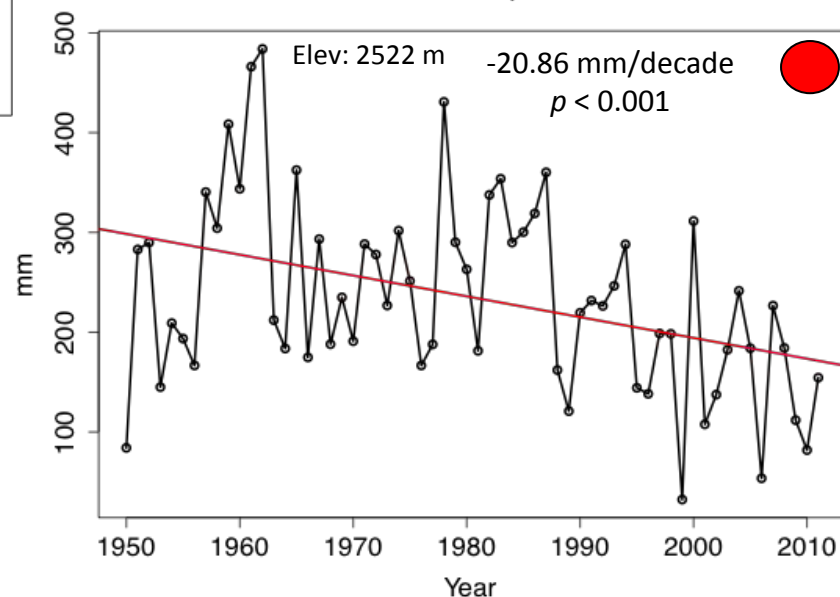


Annual Trend (1950-2011) in Oct-Nov-Dec-Jan-Feb-Mar Seasonal Precipitation for Stations in the Region

33 of the 96 station have
significant trend $p < 0.1$

8 of the 33 stations ↓

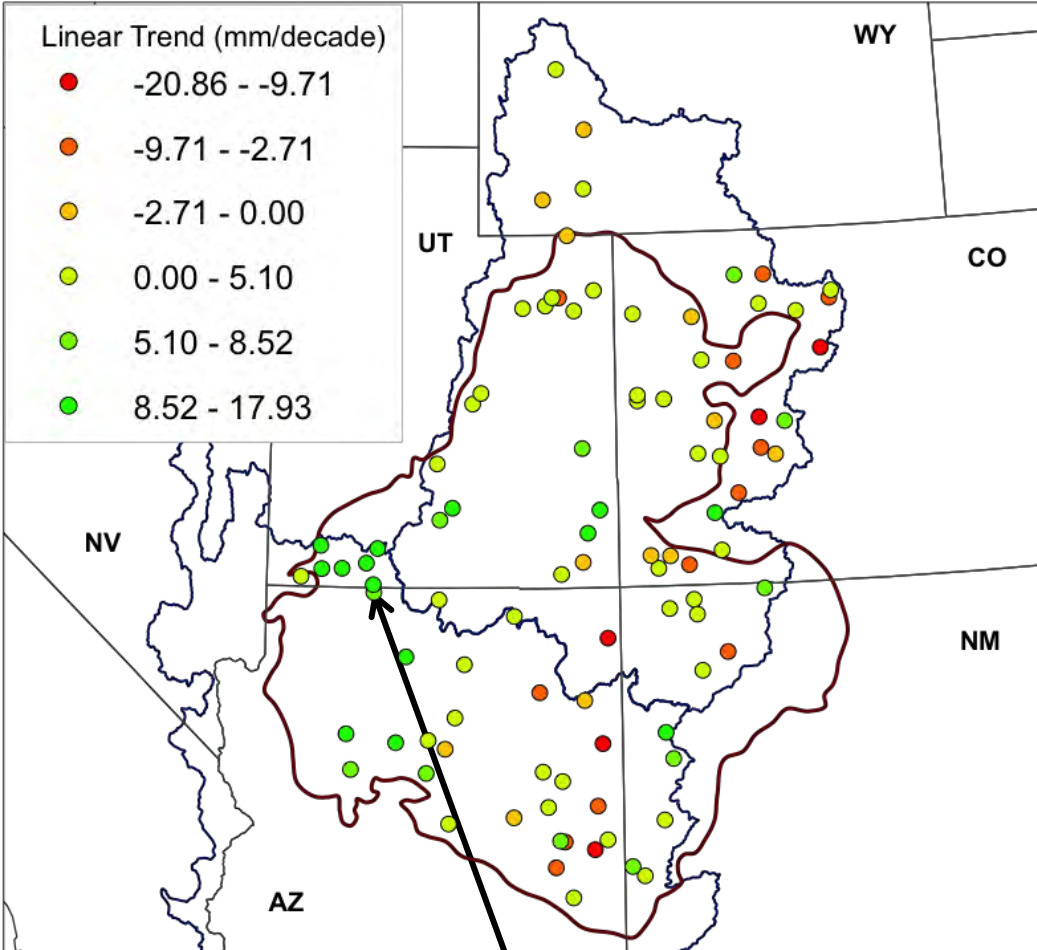
Stn_ID_23683 ONDJFM Precipitation Annual Trend



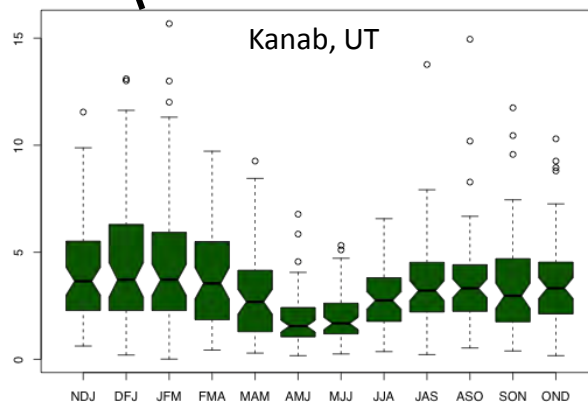
Higher elevation Site

Linear Trend (mm/decade)

- -20.86 - -9.71
- -9.71 - -2.71
- -2.71 - 0.00
- 0.00 - 5.10
- 5.10 - 8.52
- 8.52 - 17.93



Stn_ID 424508

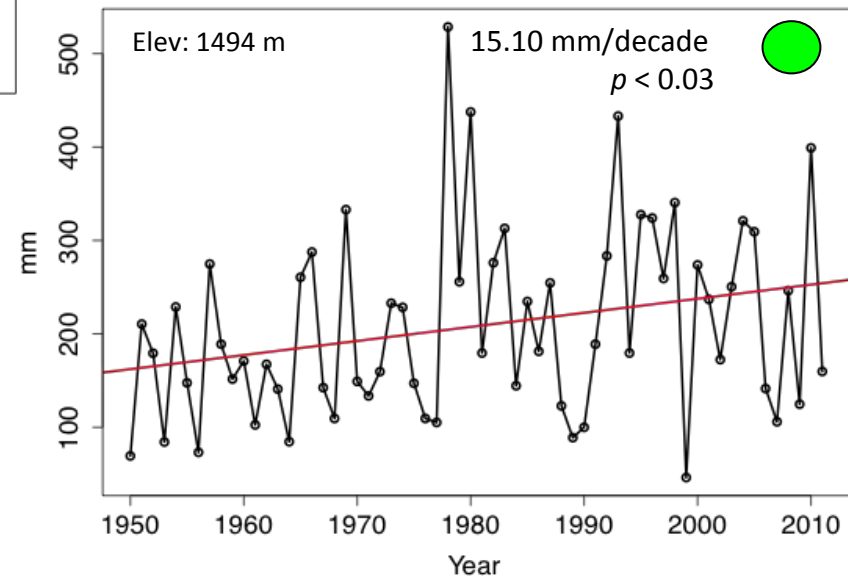


Annual Trend (1950-2011) in Oct-Nov-Dec-Jan-Feb-Mar Seasonal Precipitation for Stations in the Region

33 of the 96 station have significant trend $p < 0.1$

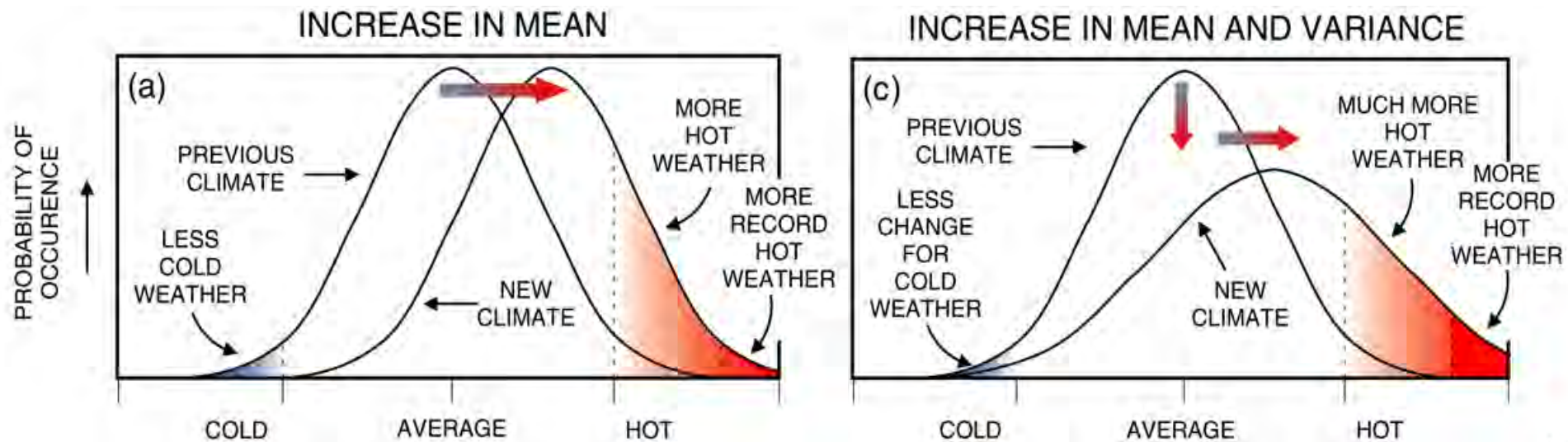
25 of the 33 stations ↑

Stn_ID_424508 ONDJFM Precipitation Annual Trend





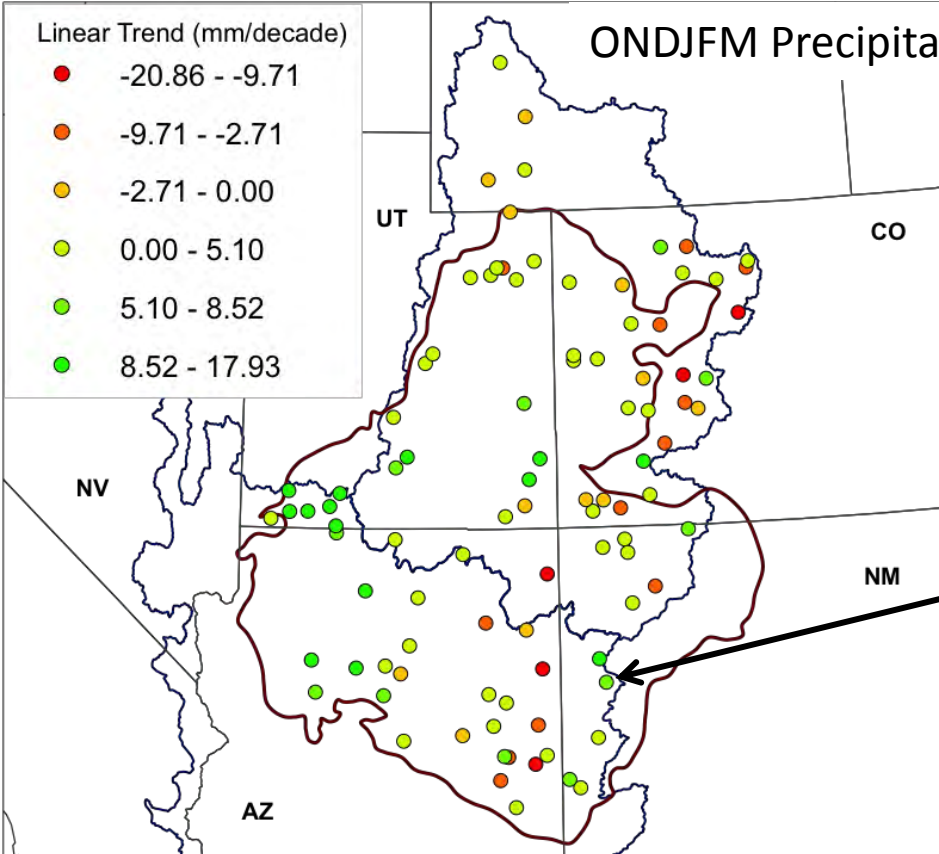
A Change in the Mean is only Part of the Story!



Linear Trend (mm/decade)

- -20.86 - -9.71
- -9.71 - -2.71
- -2.71 - 0.00
- 0.00 - 5.10
- 5.10 - 8.52
- 8.52 - 17.93

ONDJFM Precipitation Trend

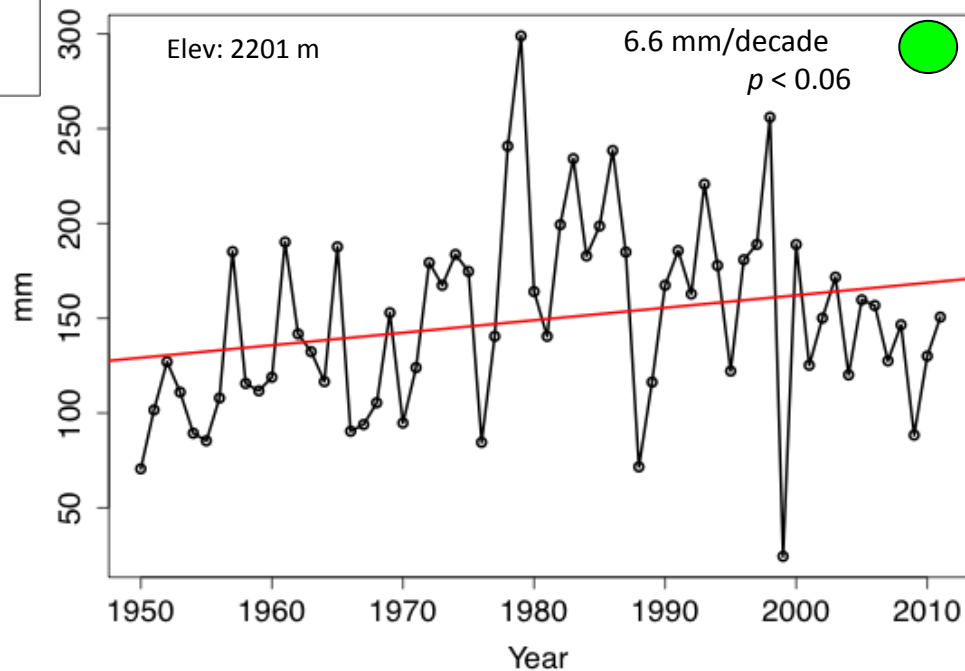
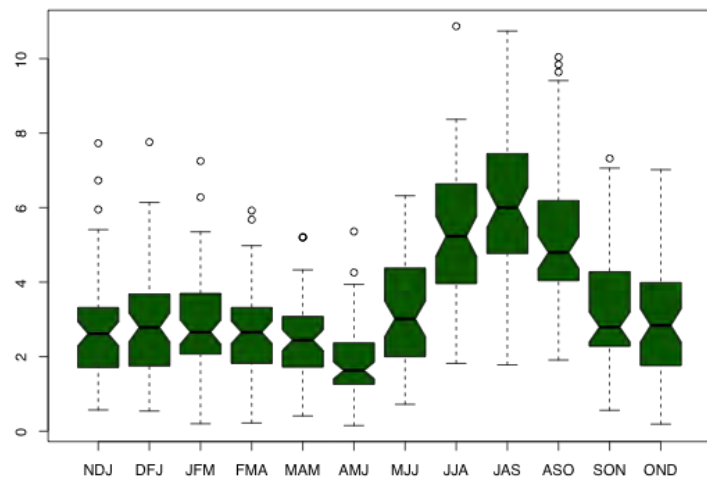


El Morro National Monument, NM



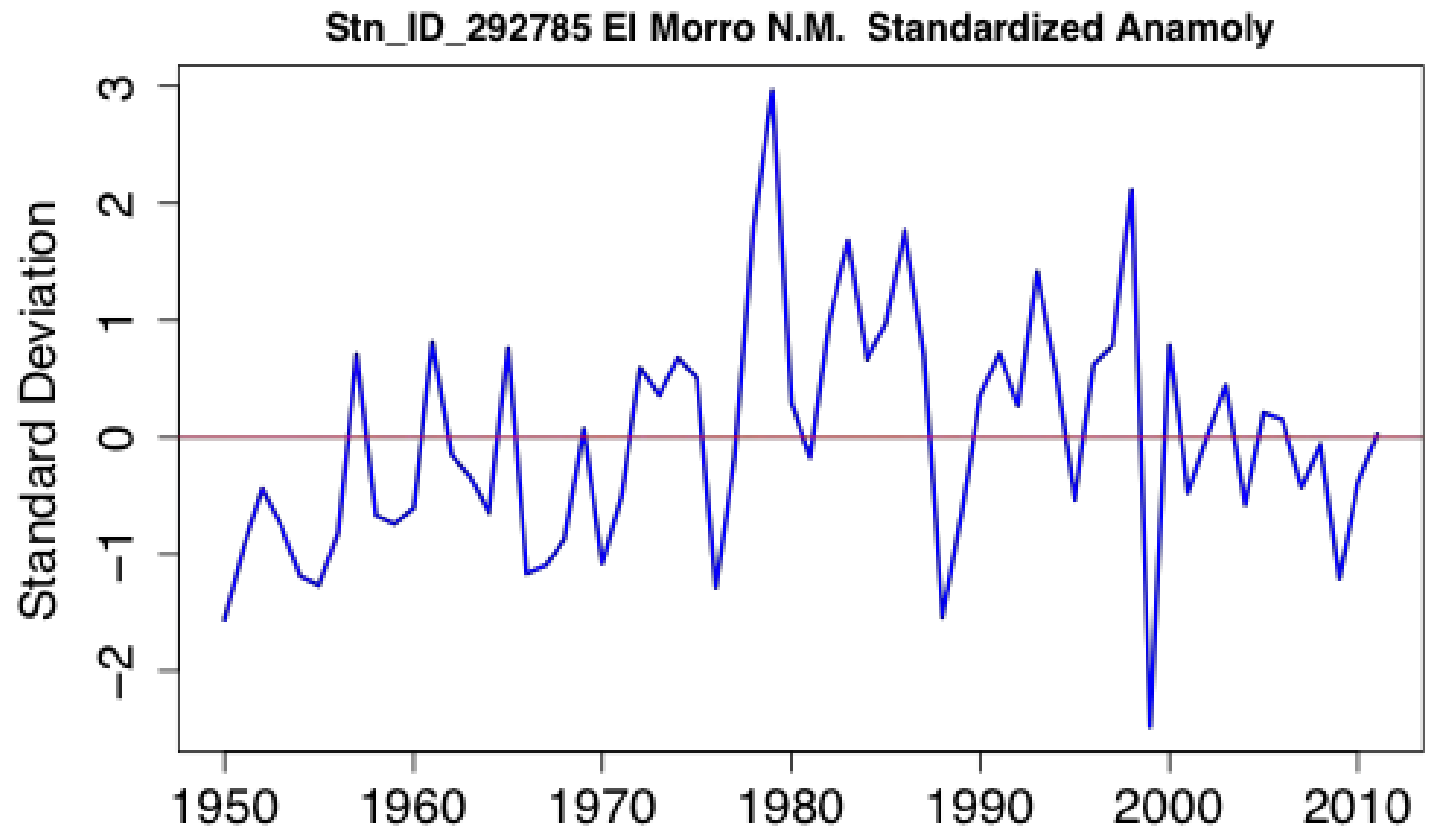
Stn_ID_292785 ONDJFM Precipitation Annual Trend

Stn_ID 292785



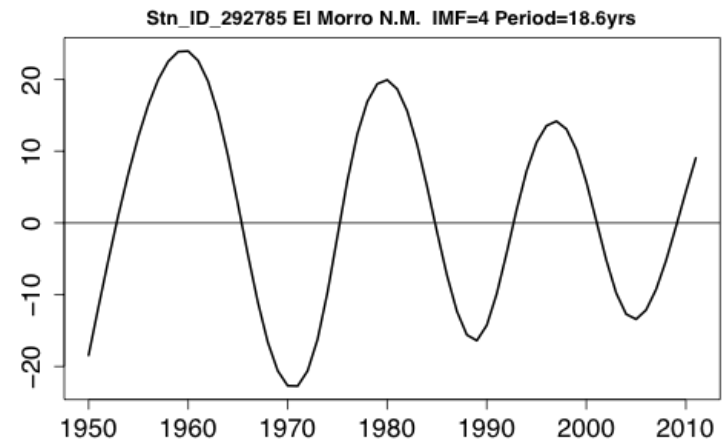
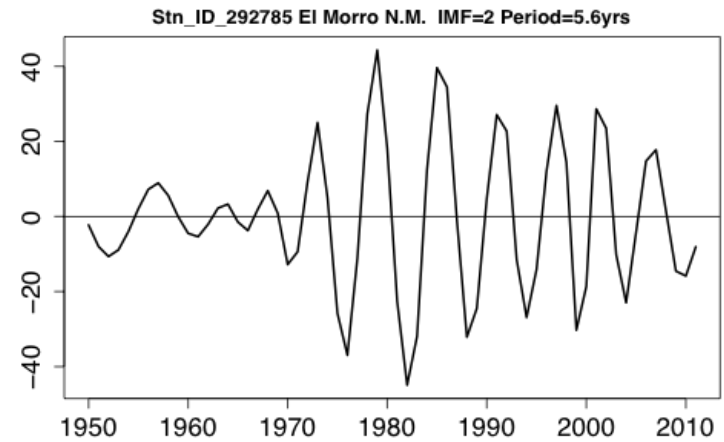
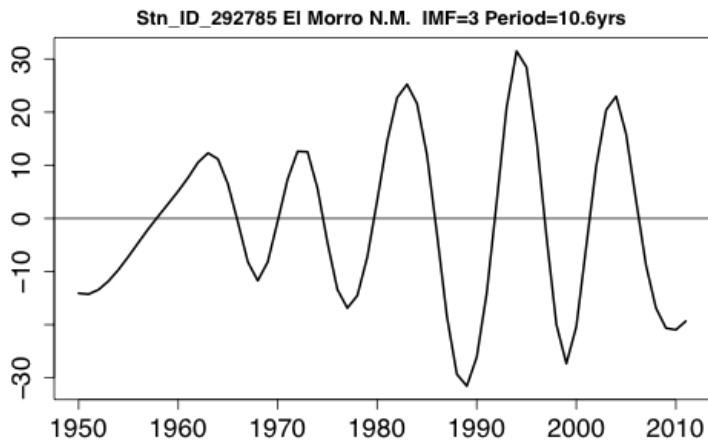
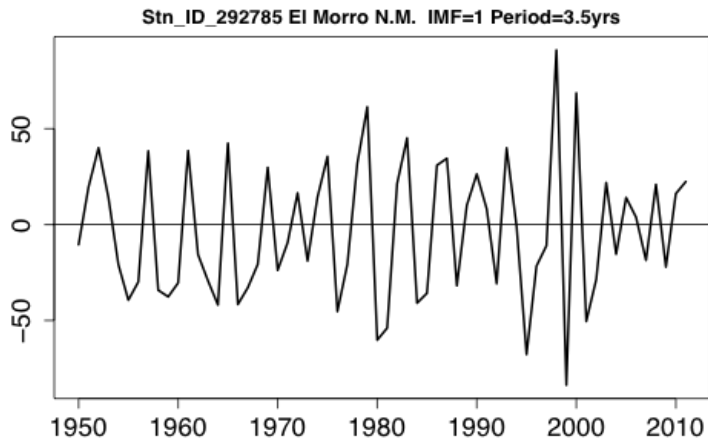
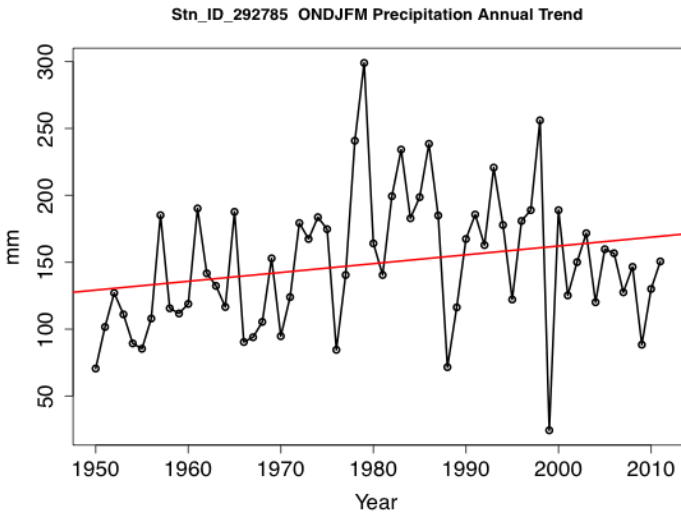


Standardized Anomaly For ONDJFM Precipitation



Empirical Mode Decomposition

Huang et al 1998. *Proc. Roy Soc London A*.454:903-995

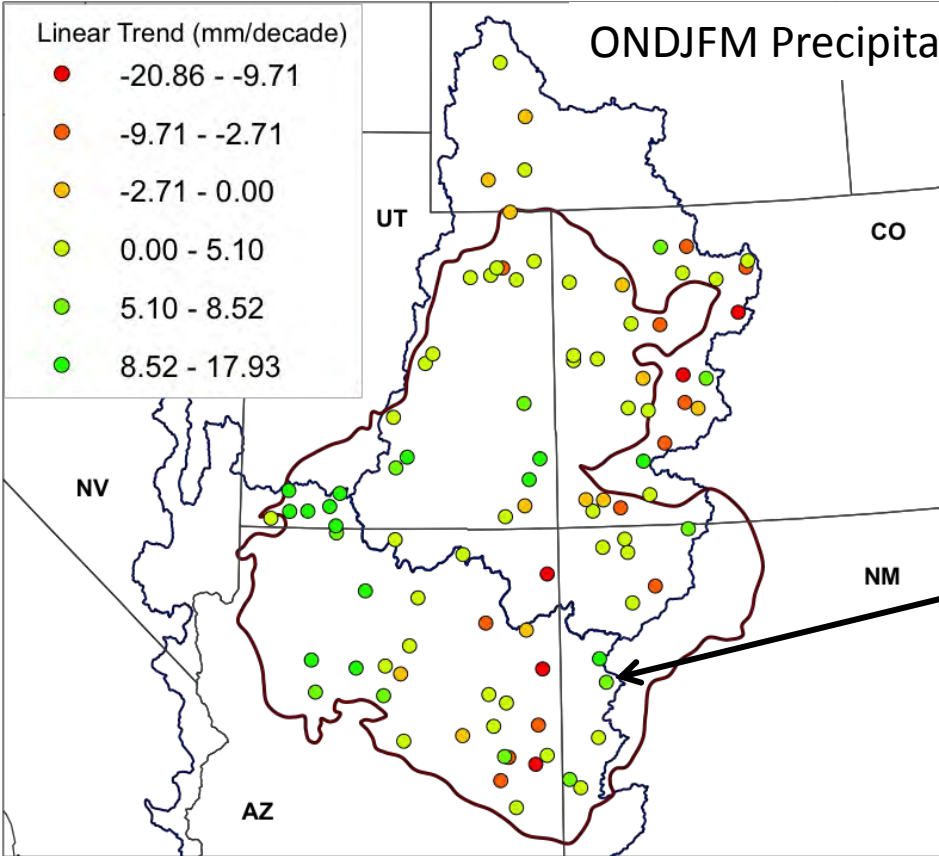


Linear Trend (mm/decade)

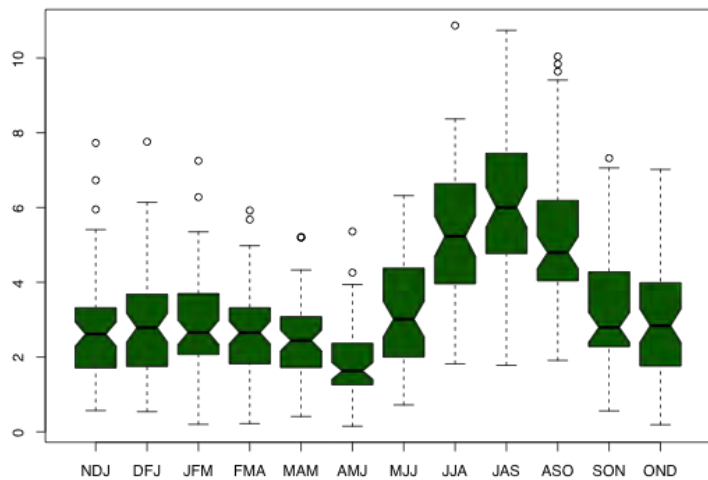
- -20.86 - -9.71
- -9.71 - -2.71
- -2.71 - 0.00
- 0.00 - 5.10
- 5.10 - 8.52
- 8.52 - 17.93

ONDJFM Precipitation Trend

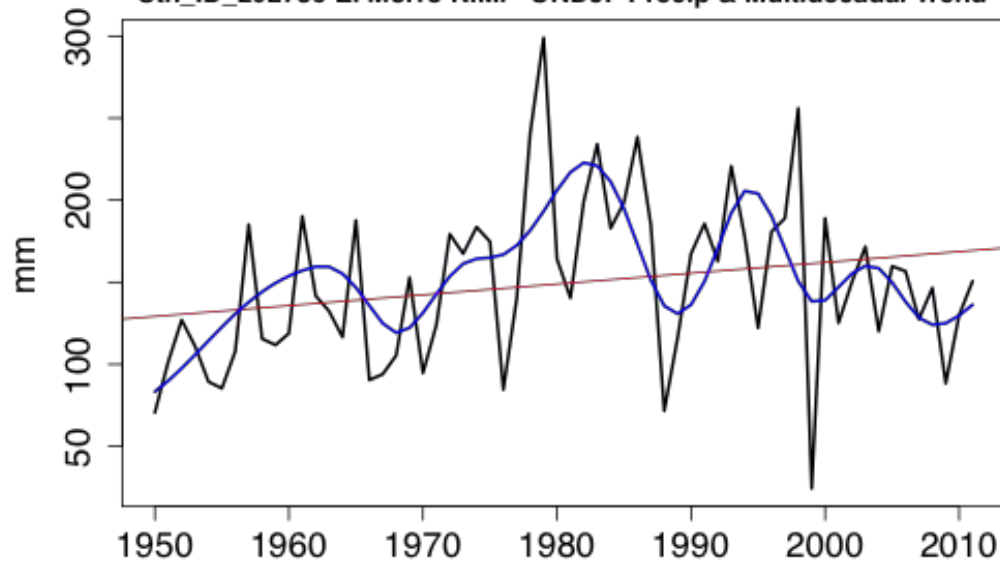
El Morro National Monument, NM

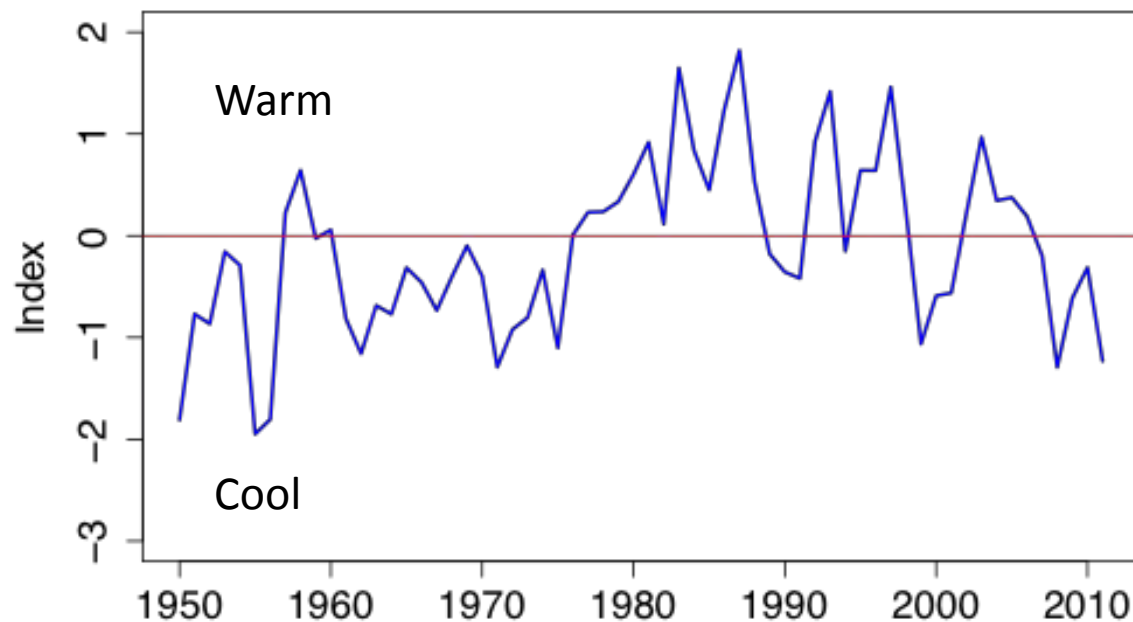
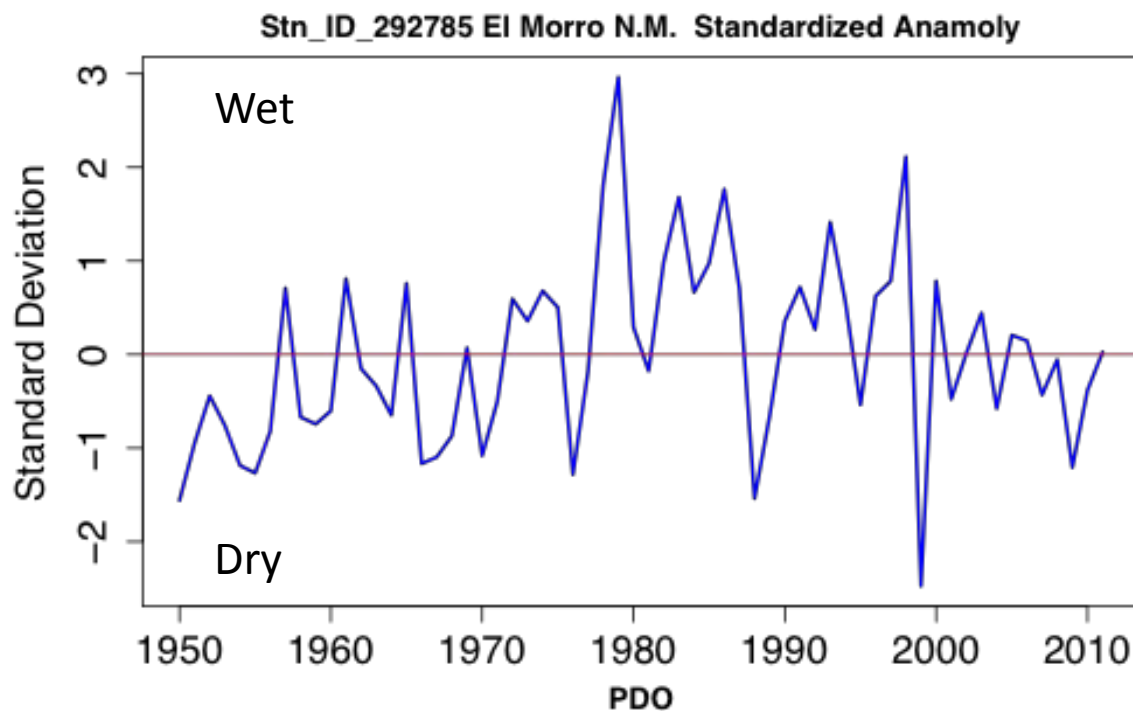


Stn_ID 292785



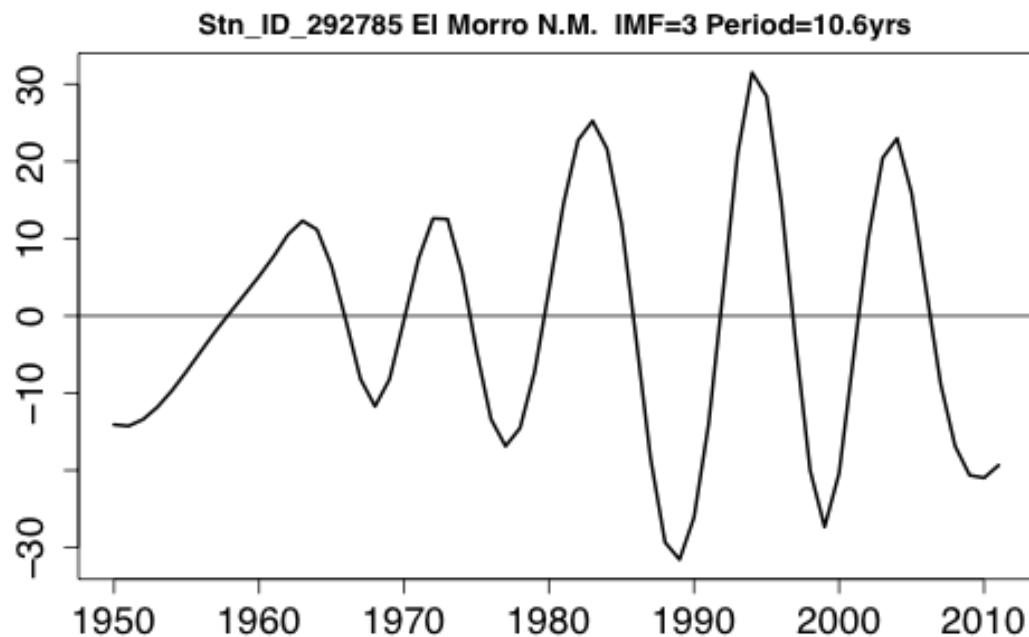
Stn_ID_292785 El Morro N.M. ONDJF Precip & Multidecadal Trend



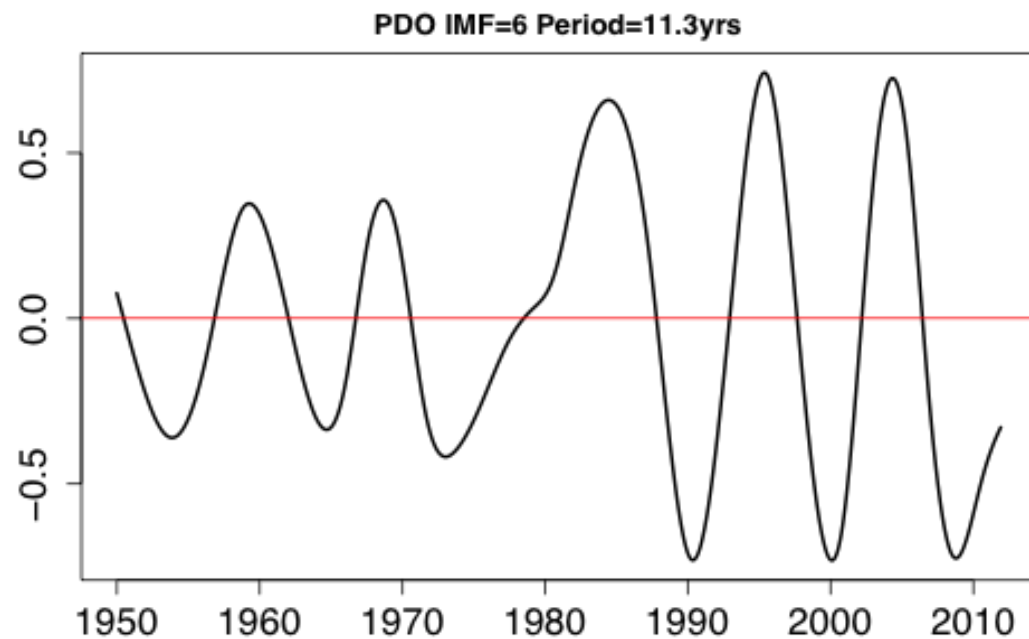


Comparison of the
Standardized Anomaly of
Oct-Nov-Dec-Jan-Feb-Mar
Precipitation and Annual
PDO Index (1950-2011)
(El Morro National Monument)

Source of PDO data: Univ. of Washington
<http://jisao.washington.edu/pdo/PDO.latest>



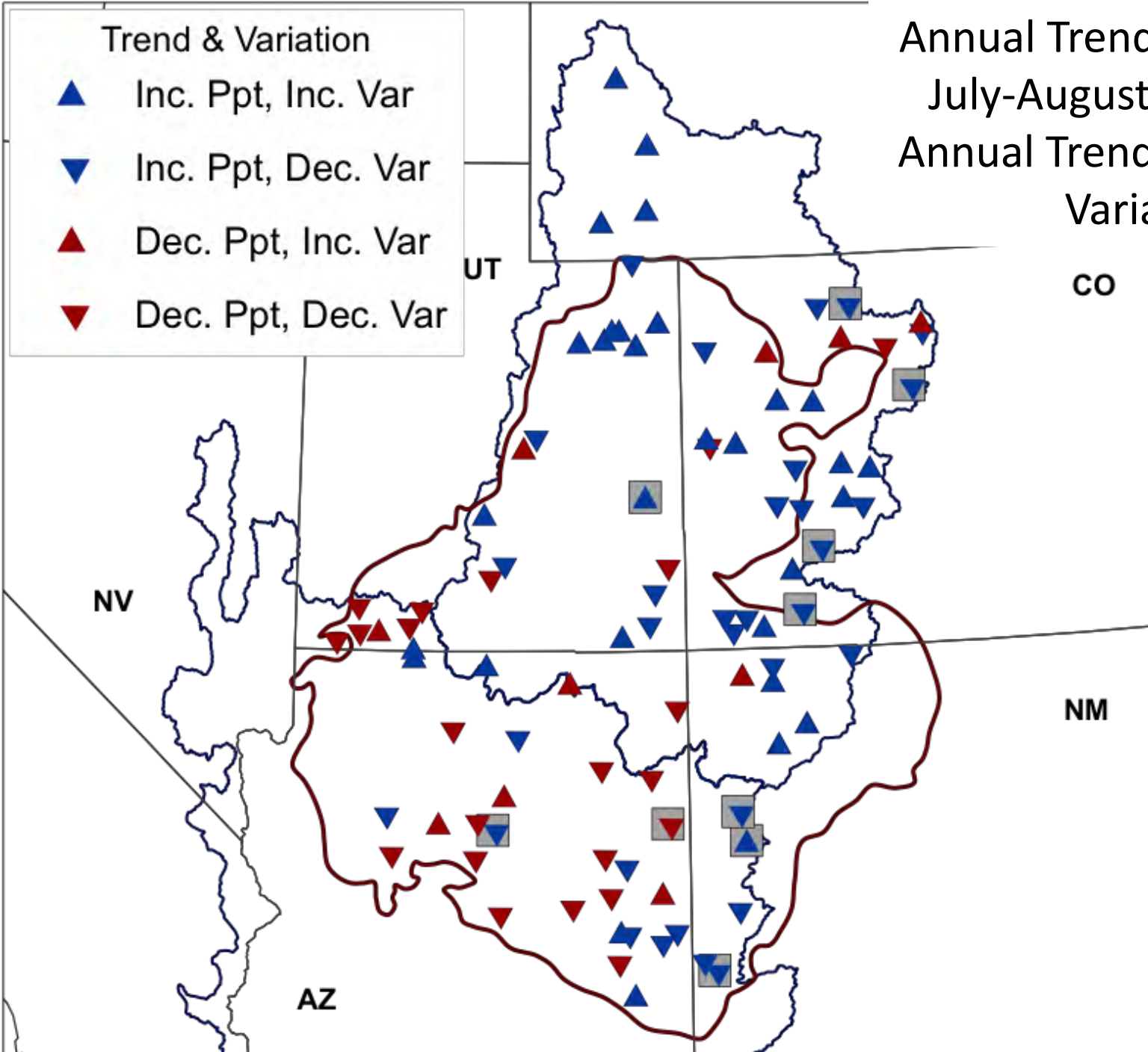
This is
Intriguing but
Needs More
Investigation!!



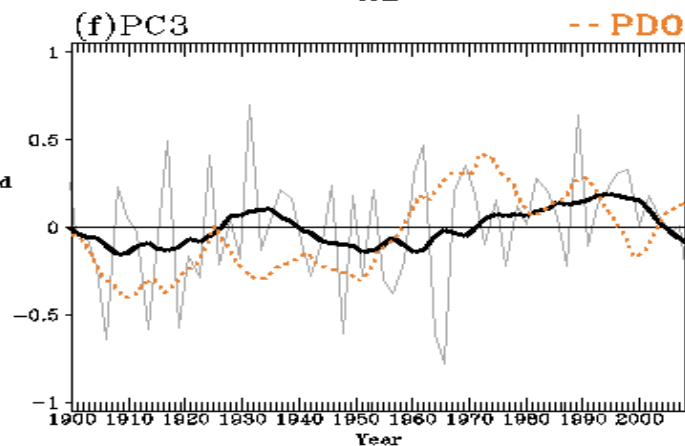
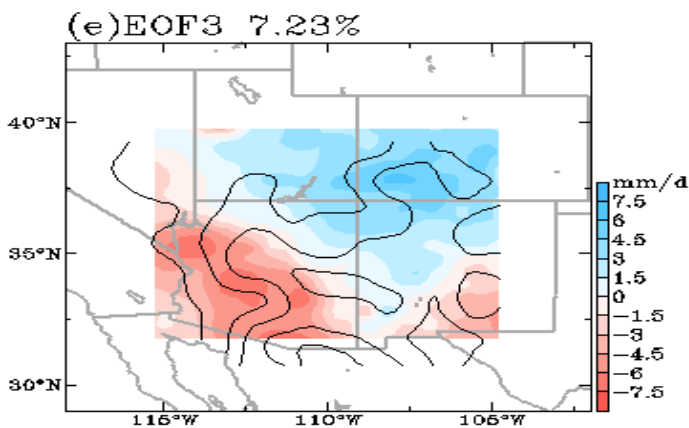
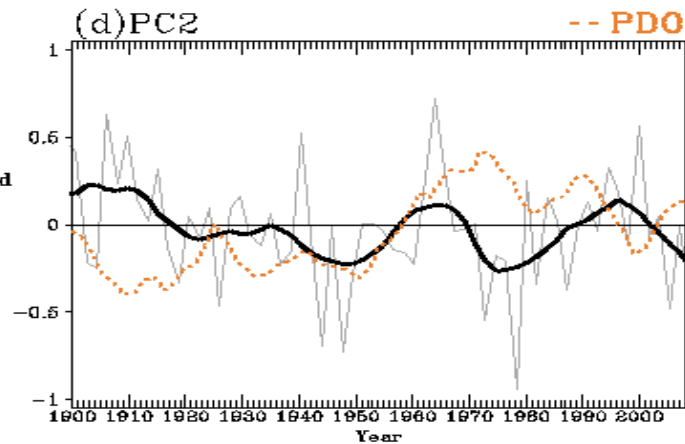
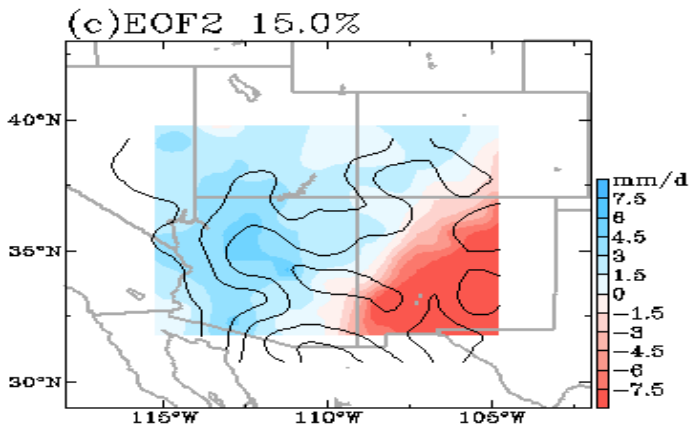
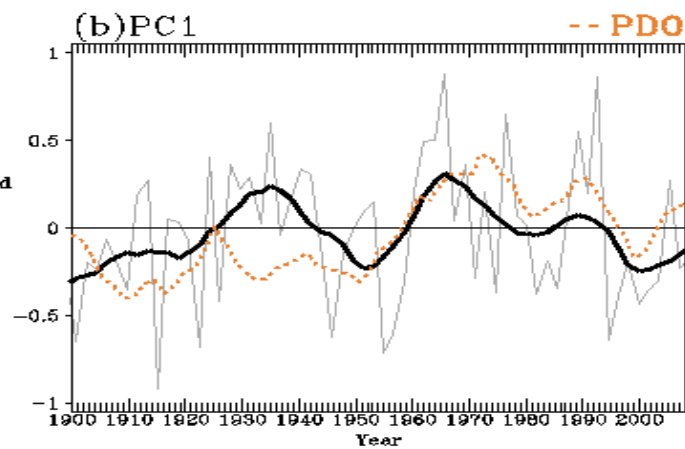
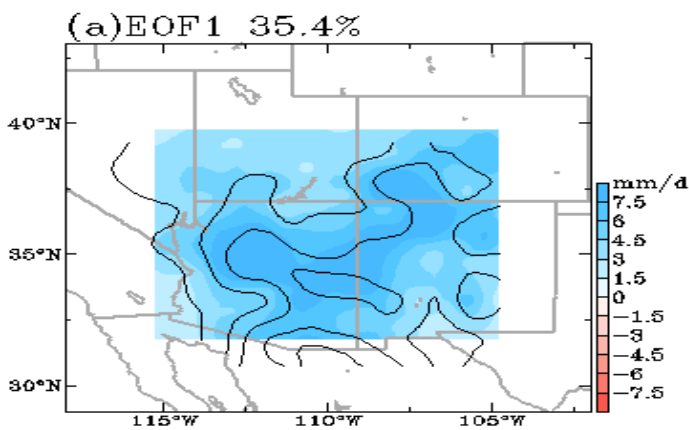
Trend & Variation

- ▲ Inc. Ppt, Inc. Var
- ▼ Inc. Ppt, Dec. Var
- ▲ Dec. Ppt, Inc. Var
- ▼ Dec. Ppt, Dec. Var

Annual Trend (1950-2011)
July-August September
Annual Trend and Decadal
Variation



Analysis of Jul-Aug-Sept NAM Precipitation

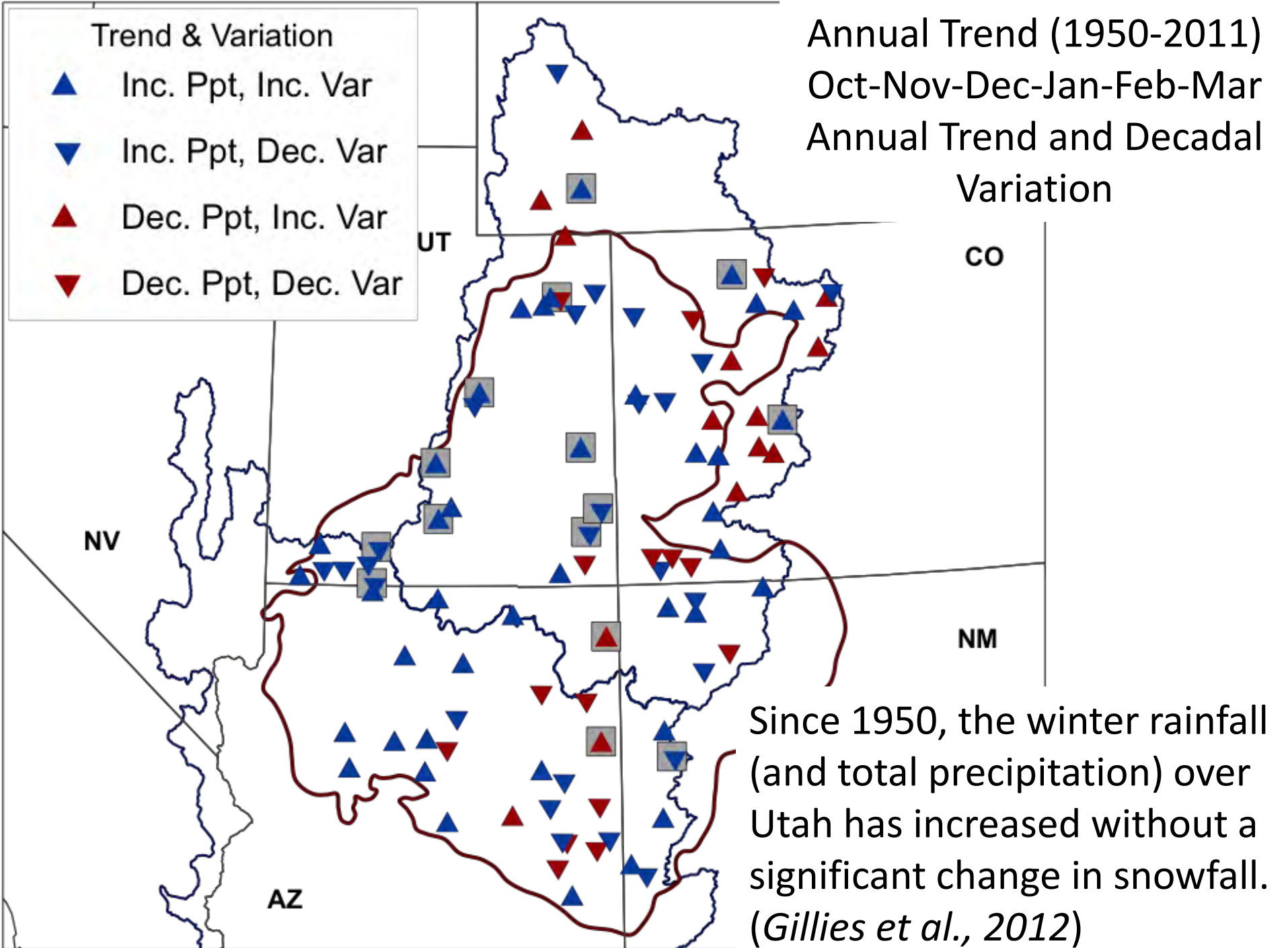


- PC1 Coefficient Series
- PDO Index
- 9 year lowpass filter

Trend & Variation

- ▲ Inc. Ppt, Inc. Var
- ▼ Inc. Ppt, Dec. Var
- ▲ Dec. Ppt, Inc. Var
- ▼ Dec. Ppt, Dec. Var

Annual Trend (1950-2011)
Oct-Nov-Dec-Jan-Feb-Mar
Annual Trend and Decadal
Variation



Summary

- Winter and summer monsoon precipitation are important factors in ecohydrology of the Colorado Plateau.
- Simulated precipitation from current climate models is inconsistent (timing and amount) with observed on the Colorado Plateau.
- Precipitation in the NW NAM region (Utah) fluctuates weakly in summer and more strongly in winter.
- Precipitation in the NE NAM region (SW Colorado) exhibits noticeable variability in summer, which is modulated by the PDO.
- Empirical Mode Decomposition provides a more robust method for analyzing non-stationary data.
- By analyzing the intrinsic functional modes of variability we may gain a better understanding of how precipitation may change in the near future.

